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# Kentucky Water Resources Annual Symposium

March 19, 2012



Marriott's Griffin Gate Resort  
Lexington, Kentucky

**UK**  
UNIVERSITY OF KENTUCKY  
Kentucky Water Resources  
Research Institute

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# **Kentucky Water Resources Annual Symposium**

March 19, 2012

Marriott's Griffin Gate Resort  
Lexington, Kentucky

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## **PAST RECIPIENTS OF INSTITUTE AWARDS FOR WATER RESEARCH, WATER PRACTICE, AND WATER QUALITY**

- **Bill Barfield Award for Water Research**

- James Dinger (2011)
- Alice Jones (2010)
- Sylvia Daunert (2009)
- Gail Brion (2008)
- David White (2007)
- Wes Birge (2006)
- Don Wood (2005)

- **Lyle Sendlein Award for Water Practice**

- Linda Bridwell (2011)
- Greg Heitzman (2010)
- Susan Bush (2009)
- Steve Reeder (2008)
- Bill Grier (2007)
- Jack Wilson (2005)

- **Bob Lauderdale Award for Water Quality**

- Amanda Abnee Gumbert (2011)
- Malissa McAlister (2010)
- Bruce Scott (2009)
- Ken Cooke (2008)
- Judith Petersen (2007)
- Eddie Foree (2006)

## PANEL DISCUSSION: WATER RESEARCH NEEDS IN KENTUCKY

Alan E. Fryar  
Associate Professor and Director of Graduate Studies  
Department of Earth and Environmental Sciences  
University of Kentucky  
alan.fryar@uky.edu

Peter Goodman, Assistant Director  
Kentucky Division of Water  
Frankfort, Kentucky  
Peter.Goodmann@ky.gov

Michael S. Griffin, Assistant Director  
U.S. Geological Survey, Kentucky Water Science Center  
Louisville, Kentucky  
mgriffin@usgs.gov

James A. Kipp, Associate Director  
Kentucky Water Resources Research Institute  
233 MMRB, University of Kentucky  
Lexington, KY 40506-0107  
Phone: 859-257-1832  
kipp@uky.edu

Four panelists were invited to present their visions/predictions of current and future water research needs in Kentucky in an opening plenary session at the 2012 Kentucky Water Resources Annual Symposium. The requested overall general focus was ground water research needs. By its general nature, ground water hydrology is located at an interdisciplinary interface with many other geosciences (including areas such as surface water hydrology, atmospheric sciences, geochemistry, ecological sciences, biological sciences, soil sciences) as well as the social and economic sciences. It is anticipated that the research needs presented will encompass many associated discipline areas.

Each panelist will be provided approximately 15 minutes to present the water-related topics that they see as current or developing research needs. The remaining time in the session will be utilized for discussion between the panelists and/or questions and comments from the audience.

## NOTES

[illegible]

## A REGIONALLY-CALIBRATED CRITICAL FLOW FOR STREAM CHANNEL PROTECTION

Bob Hawley  
Sustainable Streams, LLC  
1948 Deer Park Avenue, Louisville, KY 40205; 502.718.2912  
bob.hawley@sustainablestreams.com

Matt Wooten, Jim Gibson, Sean Blake, and Samantha Brown  
Northern Kentucky Sanitation District No. 1  
1045 Eaton Drive, Fort Wright, KY 41017; 859.578.6887  
mwooten@sd1.org, jgibson@sd1.org, sblake@sd1.org, sbrown@sd1.org

John Lyons, Chris Rust, and Kelly Kuhbander  
Strand Associates, Inc.  
615 Elsinore Place, Suite 320, Cincinnati, OH 45202; 513.861.5600  
john.lyons@strand.com, chris.rust@strand.com, kelly.kuhbander@strand.com

The critical flow for stream channel protection ( $Q_{\text{critical}}$ ) is defined as the flow, which when exceeded, increases the likelihood for sediment transport of the bed material and/or bank failure. Storms that are managed and released below  $Q_{\text{critical}}$  are predicted to result in inappreciable channel erosion. In contrast, flows that exceed  $Q_{\text{critical}}$  are more likely to contribute to channel erosion, widening, and potential impacts to water quality and adjacent infrastructure.

Using data from 23 regional streams,  $Q_{\text{critical}}$  for Northern Kentucky was estimated to range between approximately 40 and 50% of the 2-year peak flow ( $Q_2$ ) using the USGS regional equation for rural basins. The range was determined using industry standard mobility equations for the median bed material particle ( $d_{50}$ ). USGS flow gage data at five (5) of our field sites independently supported this range, indicating that the critical flow for bank failure also appeared to be correlated to approximately **40 to 50% of  $Q_2$** . For every hour of recorded flow that exceeded 40% of  $Q_2$ , there was approximately 0.5% channel enlargement in cross-sectional area at the five gage sites.

Given the relationship of watershed hydrologic alteration and overall stream quality, designing stormwater controls to minimize the frequency, magnitude, and duration of  $Q_{\text{critical}}$  exceedances has the potential to improve downstream channel stability and water quality. When scaling  $Q_{\text{critical}}$  from stream channels to watersheds draining less than or equal to 100 acres, it corresponds to a maximum discharge rate of **0.36 – 0.45 cfs per acre of development**.

Subsequent analysis shows that water quality BMPs such as bioretention basins can be optimized to achieve the  $Q_{\text{critical}}$  release rate for storms up to and including the 2-year, 24 hour SCS Type II distribution rainfall event without any additional increase in size relative to existing management policies. That is, stormwater controls can be designed for flood control, channel protection and water quality, at little to no additional cost to local developers.

## NOTES

[illegible]



## MONITORING WETLAND RESTORATION SUCCESS AT NORTH FORK OF IRISH CREEK

Brian C. Reeder, Ph.D.  
Morehead State University  
Center for Environmental Education  
Institute for Regional Analysis and Public Policy  
Morehead, KY 40351  
(606) 783-5419  
b.reeder@moreheadstate.edu

As part of an EQT Corporation mitigation plan, a forested wetland was restored along the North Fork of Irish Creek, near Blaine, KY. The restoration involved re-grading the area, extensive vegetation planting, and the establishment of a secondary channel. Geomorphic modifications were completed in May of 2010. We completed vegetation planting by August 2011. Quarterly monitoring of vegetative coverage, soil characteristics, groundwater saturation, and water quality characteristics were completed from 2010 through 2011. The hot and dry summer of 2010 was not conducive to the establishment and survival of the trees, shrubs, and herbs planted. Nonetheless, a characteristic wetland flora established. This did not include most of the planted woody species. The wetland appears to be on a successional trajectory towards establishment. The self-design features of the landscape will determine the ultimate biological community.

## NOTES

[illegible]

NC2D OPEN CHANNEL FLOW MODEL:  
DEVELOPMENT AND APPLICATIONS  
FOR STREAM RESTORATION DESIGN IN KENTUCKY

Brian J. Belcher, PhD, PE  
Beaver Creek Hydrology, LLC.  
907 National Avenue, Lexington, KY 40507, USA  
Tel: +1 (615) 794-7771; Fax: +1 (615) 794-7718;  
E-mail: [brian@beavercreekhidrology.com](mailto:brian@beavercreekhidrology.com)

NC2D is a new computer model for designing natural river patterns. The model uses an adaptive 3D mesh which is generated and allowed to deform under the forcing of the 2D depth-averaged velocity field perturbations in a sinuous or meandering river with granular bed and erodible banks. An initial solution is created from primary flow characteristics and then natural variation is accomplished using the Mersenne Twister random number generator coupled with the clock randomizer and then Box Muller transformation to obtain a normally distributed set of pools/meanders along the valley fall line. Parametric curves are fitted to sine-generated functions for each unique pool/meander sequence using a least-squares optimization routine. This same procedure is repeated for each meander until enough are spliced together to cover the valley fall line, with first-order continuity at each splice. A search technique is then used to locate the points of minimum radius of curvature, which are then resized if necessary based on momentum principles and field data collected in natural rivers. This initial solution is then allowed to migrate under steady flows using the 2D meander flow equations coupled with a bank erosion model. The program then optimizes down-valley pool/meander migration by repeating the mesh generation to obtain solutions which obtain minimal or “natural” migration (erosion/deposition) results suitable for design applications.

The model predicts river geometry and 2D velocity patterns very accurately and is useful for design of stream restoration components of water resources engineering projects. Model applications for two projects in Kentucky, one sinuous and one meandering, are presented.

## NOTES

[illegible]

## USING REMOTE SENSING TOOLS TO TARGET STREAM PROTECTION AND WASTEWATER TREATMENT BMPs IN RURAL KENTUCKY

Catherine Carter, Peter Cada, Gregory D. Sousa, PE, and Barry Tinning  
Tetra Tech, Research Triangle Park, NC  
919.485.8278

catherine.carter@tetrattech.com, peter.cada@tetrattech.com,  
gregory.sousa@tetrattech.com, barry.tinning@tetrattech.com

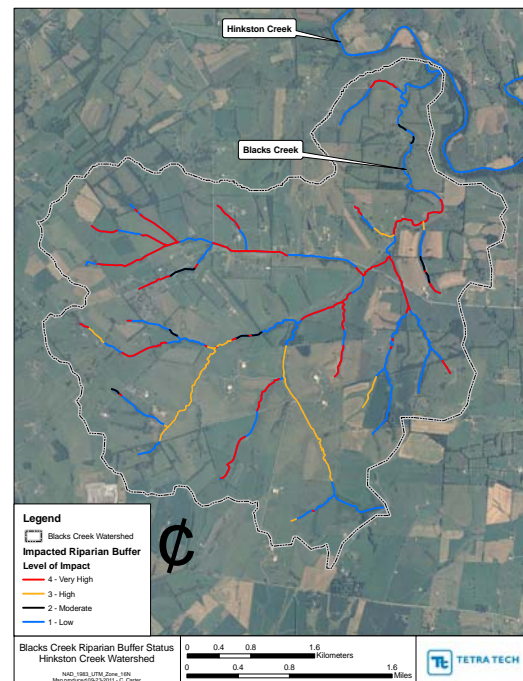
Remote sensing tools – such as GIS mapping, aerial photography, and tailored analysis – can help to identify areas with high risks from septic systems, inadequate riparian vegetation, and livestock concentrations near streams. Results for such analyses can be used to identify pollutant source areas and target management practices. For the Hinkston Creek Watershed CWA 319 Project in east central Kentucky, Tetra Tech produced an onsite wastewater system risk analysis, a riparian buffer assessment, and a focused study of two selected tributaries affected by livestock access to the stream corridor.

Onsite wastewater treatment system potential risk to water quality was assessed via mapping analyses that considered system densities (i.e., number per square mile), system age, and proximity to surface waters. Prioritization was based on level of household density, closeness to streams, and closeness to karst topography (to account for impacts to groundwater). Publicly serviced areas with centralized wastewater treatment were eliminated first; household density was calculated for areas outside of public sewer line boundaries in the areas surrounding the municipalities – within 2 miles of publicly serviced areas in Mount Sterling and within 1 mile of publicly serviced areas for all other municipalities. Household density was not calculated across the entire watershed because septic failure impacts to water quality were assumed to be low in agricultural areas where household density is less than 1 house per acre. Data for calculating household density was obtained from the U.S. Census Bureau's 2000 Census Block data. Closeness to streams was calculated using the high resolution streams data layer created by the United States Geological Survey (USGS) as part of the National Hydrography Dataset (NHD; USGS, 2007). Closeness to karst was calculated using a geologic data layer developed by the Kentucky Geological Survey. Only areas having a household density greater than one household per acre were considered and household density, closeness to streams, and closeness to karst geology received equal weights throughout the prioritization process. Eight census blocks within the Hinkston Creek watershed received prioritization ratings at levels of medium priority (7 blocks) and high priority (1 block). All other census blocks included in the prioritization analysis received ratings of low priority due to low levels of household density (<1 house per acre).

The riparian buffer assessment and deficiency analysis used aerial photography to determine canopy cover presence/absence and buffer zone widths. The stream layer used for the analysis was the high resolution streams data layer created by the United States Geological Survey (USGS) as part of the National Hydrography Dataset (NHD; USGS, 2007). These streams were buffered to create polygons representing riparian buffer areas

for this analysis. A 100-foot buffer was created along each side of the mainstem of Hinkston Creek downstream from the Grassy Lick/Hinkston confluence. A 50-foot buffer was created along each side of Hinkston Creek upstream from the Grassy Lick/Hinkston confluence and along all tributaries within the Hinkston Creek watershed. A Multi-Resolution Land Characteristics Consortium (MRLC) geospatial dataset known as the Landscape Fire and Resource Management (LANDFIRE) map, that provides vegetation and wildland fuel maps, was obtained to determine riparian buffer health status (impacted vs. intact). Using methodology from a recent study (Roy et al., 2005), any vegetated layers with less than 30 percent coverage were lumped together with other impacted riparian habitat LULCs (e.g., developed, open space, pasture/hay, etc.). The percent buffer deficiency within each assessment subwatershed was estimated using GIS. The riparian buffer deficiency, at the assessment subwatershed level, ranges from 45 percent to 100 percent throughout the Hinkston Creek watershed. The riparian buffer deficiency for the entire watershed is 75 percent.

A broader, desktop analysis of high-risk stream channel areas was also conducted via mapping work that analyzed riparian vegetation (i.e., canopy cover), cattle access points, and property ownership records. The riparian deficiency data described above was overlaid with imagery from the National Agriculture Imagery Program (NAIP), downloaded from the USDA: NRCS Geospatial Data Gateway website. This was used to assess the intensity of impact on riparian areas within the Blacks and Boone Creek watersheds. Imagery used covered all of Bourbon County and was acquired by NAIP during the agricultural growing season in 2010. Reaches within each watershed were visually scanned against the NAIP imagery to assess the land cover context for riparian buffers. Impacted riparian areas were divided into four levels of impact based on stress conditions observable from the aerial imagery, such as proximity of intense tilling and/or grazing to the stream edge, cattle access points, and lack of tree or shrub cover in the riparian buffer. Best professional judgment was used to assign a level of impact to each reach segment according to the definitions of levels of impact. Cattle access points were visible along some reach segments from the aerial imagery. Evidence of bare stream or pond banks that were within observable pasture boundaries were considered cattle access points. These points were highlighted for the targeted streams (see figure). Parcel boundaries were obtained from the Bourbon Counter Property Valuation Administrator to identify landowners who might be interested in stream protection BMPs. A table identifying high risk areas and parcel owners was developed to support BMP implementation efforts.



## IMPROVING WATER QUALITY THROUGH STREAM RESTORATION AT TOWN BRANCH: AN URBAN WATERSHED CASE STUDY

Eric Dawalt, P.E.  
Ridgewater, LLC  
908 Woodglen Ct.  
Lexington, KY 40515  
(859) 806-1089  
edawalt@insightbb.com

Russ Turpin  
EcoGro  
P.O. Box 22273  
Lexington, KY 40522  
(859) 231-0500  
russ@ecogro.net

Improving stream water quality and restoring physical stream stability and habitat have both been shown to increase aquatic life and stream health. However, physically degraded, urban streams with poor water quality from non-point source pollution have often been excluded from receiving regulatory agency and/or funding support due to concerns that restoring the physical habitat could be in vain if the water quality is too poor to support robust aquatic life.

Town Branch (a tributary to Strodes Creek in Clark County), is a typical stream for the Bluegrass Region in Central Kentucky. It has many of the issues and ailments of urban waterways in this area including anthropogenic alterations such as channel straightening and dredging, draining of adjacent wetlands, sewer/utility lines, non-point source pollution from urban runoff, and limited riparian forest buffer.

The Kentucky Transportation Cabinet (KYTC) partnered with the Strodes Creek Conservancy to restore approximately 7000 feet of degraded Town Branch channel on City of Winchester property as an advance stream mitigation site. Due to concerns that the runoff from the mostly urban watershed would cause poor water quality in the stream, the U.S. Army Corps of Engineers and Kentucky Division of Water set high standards for biological success for the project.

To ensure the project met the biological success criteria, KYTC incorporated several measures into the stream restoration project to improve stream water quality, in addition to restoring the physical stability and habitat of the stream. This presentation highlights innovative features and techniques used to improve stream water quality as part of stream restoration in an urban watershed.

## NOTES

[illegible]



## UNIVERSITY-HABITAT FOR HUMANITY GREEN INFRASTRUCTURE DEMONSTRATION PROJECT

Nancy Givens, Sustainability Programs Development Coordinator  
and Terry Wilson, Director  
WKU Center for Environmental Education and Sustainability,  
1906 College Heights Blvd., #11098, Bowling Green, KY 42101  
270-745-2842 or 270-745-4424  
nancy.givens@wku.edu    terry.wilson@wku.edu

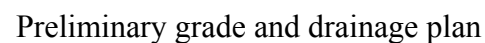
Western Kentucky University is working in partnership with the local and state Habitat for Humanity to create an integrated green infrastructure statewide demonstration project using Low Impact Development (LID) techniques to manage stormwater as part of a planned medium density green affordable housing community, funded by a 2010 319(h) grant. The site is a 16-acre parcel owned by the local Habitat for Humanity within the Jennings Creek watershed and Bowling Green city limits. The project will promote enhanced water quality and public awareness through Best Management Practices (BMPs), professional and community education and outreach, and cooperation among agencies, citizens, and government. Education and media outreach and professional training are essential to the project. The state Habitat for Humanity will seek building policy revisions with implications for local, state, and potentially international chapters.

The goal of this project is to demonstrate an integrated green infrastructure model for community development that can be broadly replicated to reduce NPS pollution, educate the public, and improve quality of life for communities. Objectives are to:

1. Create an integrated green infrastructure that retains, filters, and reuses all stormwater at the site
2. provide professional training and community education and outreach on the features of this system and how they reduce NPS pollution and benefit the community and environment
3. involve residents and community in hands-on activities to build a sense of pride and ownership in the project and shared responsibility for stewarding the environment
4. seek building policy revisions for KyHFH and potentially state and local governments.

Committed partnerships are a strength of this project. Principle partners include Western Kentucky University (WKU) and the state and local Habitat for Humanity. Additional partners include the Bowling Green Mayor's office and Department of Public Works, WKYU-PBS, Bowling Green City Schools, BGGreen Partnership for a Sustainable Community, Bluegrass PRIDE, Arnold Consulting and Engineering Service (A-CES), and the Warren County Division of Stormwater Management. The project will work closely with the River Basin Coordinator and River Basin Team in the project area. An Advisory Board will include representation from each of the principle partners.

- Stormwater Control (e.g., pervious pavement, thick gravel sub-base, arced headwall, rain garden)
- Water Runoff Control (e.g., broad outlet structure, modified drainage channels, landscaping/vegetation)
- Sediment/Trash Control (e.g., stilling basin, filtration fence)
- Pollution/Irrigation Control (e.g., drought tolerant and native species plantings to reduce pesticide and water use; subsurface cisterns, rain barrels, above ground water features, and irrigation piping)



EFFECTIVENESS OF POLLUTANT REMOVAL IN THE MCCONNELL SPRINGS  
STORMWATER QUALITY WETLAND POND AND THE GAINESWAY POND  
RETROFIT PROJECT, YEAR TWO

David J. Price, Ph.D. and Susan L. Plueger, P.E.  
Lexington-Fayette County Government, Division of Water Quality  
301 Lisle Industrial Avenue, Lexington, KY 40511  
(859) 425-2415  
dprice@lexingtonky.gov

In December 2009, the Lexington-Fayette Urban County Government (LFUCG) completed construction of the McConnell Springs Stormwater Quality Wetland Pond. The facility has a “treatment train” of 3 components: a pre-treatment gross debris trap, a three-cell settling forebay, and the main pond with 0.2 acres of deep pool and 0.5 acres of shallow marsh/littoral shelf area. The main purpose of this facility is to reduce non-point source pollution entering McConnell Springs and neighboring streams Wolf Run, Town Branch, and South Elkhorn Creek, all designated as impaired streams by the Kentucky Department for Environmental Protection. The project’s secondary purpose is to demonstrate to the public the benefits that natural environments provide to water quality and quantity control. In Spring 2009, LFUCG remediated Gainesway Pond at Centre Parkway. The renovations were part of the Gainesway Retention Basin Water Quality and Environmental Education Project. The goal of this project was to retrofit the existing Gainesway Pond to increase pollutant removal through addition of constructed wetlands, aquatic plantings, an aerator, and upstream biofiltration and gross debris traps. The Gainesway project also provides the community with environmental educational opportunities. Both of these projects were funded in part through a §319(h) grant provided by the U.S. Department of Environmental Protection and administered by the Kentucky Division of Water.

To monitor pollutant reduction performance, LFUCG Division of Water Quality collected water samples in 2010-2011, with emphasis on runoff samples during storm events. At McConnell Springs, the Friends of Wolf Run Inc. provided training to community volunteers who assisted with sample collection. As a public outreach and education component, McConnell Springs Nature Center staff set up a mechanism for science students to help augment field data. At McConnell Springs, five sampling sites were identified: sites M1-M3 were located in the pre-treatment and forebay cells prior to the main pond (M4-M5). Gainesway Pond samples were collected from the following sites: upstream, mid-stream, wetland area, Pond A, and Pond B (i.e., GP1-GP5). A total of 13 sampling events were conducted at McConnell Springs and 8 sampling events at Gainesway Pond in 2010-2011. On-site measurements included: temperature, pH, ORP, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS). Additional analysis included: alkalinity, hardness, carbonaceous biological oxygen demand (CBOD<sub>5</sub>), total suspended solids (TSS), total ammonia, nitrate, nitrite, total phosphorus, orthophosphate, and bacterial enumeration (fecal coliforms, *E. coli*, and other coliforms). Metal analyses of water samples from McConnell Springs were conducted in 2010 by the Kentucky Geological Survey (KGS) Laboratory.

During sampling at McConnell Springs Wetland Pond, pH ranged from 7.0 to 9.8 in 2010, and from 7.53 to 9.85 in 2011, which were within expected parameters. No distinct trends in DO concentrations were observed in 2010, with DO levels ranging from 3.03 to 8.4 mg/L. In 2011, DO ranged from 1.61 to 11.86 mg/L with levels increasing through the system and sites M4-M5 having the highest DO. Initially, both total alkalinity and hardness were elevated, but concentrations decreased as the system became established. For 2010 collections, TSS concentrations at sites M1-M3 averaged 29 mg/L, whereas sites M4-M5 averaged 12 mg/L, indicating an initial settling of suspended solids. TSS levels were observed to increase in the summer-fall and decrease in the winter. Reductions of TSS in the system were more evident in 2011. Overall ammonia levels in 2010 decreased at sites M4-M5, except for an increase in 8/27/10, attributed to low-flow conditions. As with TSS, ammonia reductions were more evident in 2011. Similar reductions were found for nitrate and nitrite. Concentrations of total phosphorous and orthophosphate decreased through the system for 2010 and 2011. Testing for fecal coliforms began in 2011 with counts generally highest at sites M1-M3. The 2010 geometric mean for *E. coli* was 674 MPN/100 mL and decreased to 344 MPN/100 mL in 2011. In general, *E. coli* counts were highest at sites M1-M3, with reductions at sites M4 and M5. The geometric mean for other coliforms in 2010 was 16210 MPN/100 mL and decreased to 4911 MPN/100 mL in 2011. For the 30 metals tested in 2010, the following were not detected in any of the sites: antimony, beryllium, cadmium, chromium, gold, lead, selenium, silver, thallium, strontium, and vanadium. Concentrations of aluminum, copper, iron, nickel, sulfur and zinc decreased through the stormwater facility.

pH levels in Gainesway Pond samples collected in 2010 were fairly constant, ranging from 7.23 to 8.85, and in 2011 the pH ranged from 7.17 to 9.20. DO levels in 2010 were elevated during high-flow conditions (4/2/10 and 12/2/10), but decreased in the summer. In 2011, lowest DO levels were observed at the wetland site (GP3), but increased in the downstream ponds (GP4-5). For both years, total alkalinity and hardness concentrations were lower in the ponds as compared to upstream stations. TSS values from 2010 were initially lower in the ponds, but the levels increased in subsequent collections (12/2/10; GP1= 2 mg/L, GP4= 8 mg/L). This trend was more evident in 2011, with highest TSS values at the ponds (GP4-5). Average ammonia concentrations did not vary between 2010 and 2011, ammonia levels for 2011 were elevated in the spring, but decreased through the system during the rest of the year. Total phosphorous and orthophosphate increased during in spring-summer 2011, but remained somewhat constant during fall-winter. Except for the April 2011 collection, *E. coli* counts were highest upstream and decreased in the ponds. Numbers for other coliforms decreased in the ponds during summer-fall, but were elevated in April and December 2011. As with McConnell Springs, fecal coliform testing began in 2011, with counts generally highest at upstream sites and decreasing in the ponds.

Based on the two year data, the structures appear to be performing as expected, with the systems becoming established and providing more consistent results. Pollutant reductions were observed at both systems. As part of their management, LFUCG will continue to monitor water quality as the systems further become established. In particular, close monitoring of ammonia, total phosphorous and bacterial counts will aid in preventing detrimental impacts to the facilities and receiving waters.

## COCA-COLA STORMWATER REPLENISH PROJECT

Eric Dawalt, P.E.  
Ridgewater, LLC  
908 Woodglen Ct.  
Lexington, KY 40515  
(859) 806-1089  
edawalt@insightbb.com

Russ Turpin  
EcoGro  
P.O. Box 22273  
Lexington, KY 40522  
(859) 231-0500  
russ@ecogro.net

In 2010, the Lexington-Fayette Urban County Government (LFUCG) initiated a stormwater utility fee to provide funding for measures to reduce the negative impacts of stormwater runoff and non-point source pollution in our local waterways. Spurred by the EPA Consent Decree, our community began to realize the daunting task of rehabilitating the urban landscape so that our waterways can support their designated uses. It was obvious that upgrading city stormwater infrastructure alone could not accomplish this task. The city of Lexington needed its citizens and businesses to make changes on their own properties.

Using a portion of the funds generated from the stormwater utility fee, the LFUCG Division of Water Quality established the Stormwater Quality Projects Incentive Grant Program to assist land owners in improving stormwater runoff quality from their properties. The grants were competitive and scored based on the project's overall effect to improve stormwater quality. One of the first projects funded by the program was the Coca-Cola Stormwater Replenish project at the Lexington Coca-Cola facility on Leestown Road.

As part of the Replenish Project, Coca-Cola installed stormwater quality Best Management Practices (BMP's) that include an 8,500 square foot rain garden (one of the largest in Lexington), a 12,500 gallon underground infiltration chamber system and a parking lot water quality sump drop inlet. It also includes a 10,000 gallon rain water harvesting system that stores rooftop stormwater runoff for beneficial use in non-potable applications such as vehicle washing, toilets, and irrigation. It is anticipated that the BMP's will treat and infiltrate up to 1.5 million gallons of stormwater each year and that Coca-Cola will be able to use over 120,000 gallons of rain water each year in non-potable applications.

In addition, Coca-Cola is partnering with two University of Kentucky (UK) groups to educate others about stormwater quality BMP's. The UK Tracy Farmer Institute for Sustainability and the Environment is using the project as a case study for water educators, K-12 teachers, and professional development courses for engineers. The UK Biosystems and Agricultural Engineering Department is utilizing it as a research project, monitoring the project for its performance and providing real data that LFUCG, facility managers, and others can use in the design of future BMP's.

## NOTES

[illegible]

## ITEST AND LFUCG STORMWATER PROFESSIONAL DEVELOPMENT

Carol D. Hanley, Ed.D.

Environmental and Natural Resources Initiative, College of Agriculture  
Associate Director, Tracy Farmer Institute for Sustainability and the Environment  
200 E Kentucky Tobacco Research & Development Center  
1401 University Drive  
Lexington, KY, 40546-0236  
(859) 257-3780  
chanley@email.uky.edu

Brian Radcliffe

Environmental and Natural Resources Initiative, College of Agriculture  
Tracy Farmer Institute for Sustainability and the Environment  
(859) 608-5258  
brian.radcliffe@uku.edu

The College of Agriculture of the University of Kentucky through the Environmental and Natural Resources Initiative (ENRI) and the Tracy Farmer Institute for Sustainability and the Environment (TFISE) has provided professional development for K – 12 teachers and learning experiences for students across Kentucky in Community Based Science projects involving water quality and geospatial technologies for the past several years. Funding has been provided through grants from the National Science Foundation's Innovative Technology Experiences for Students and Teachers (ITEST) and, more recently, through the Lexington-Fayette Urban County Government Stormwater Initiative.

Through the ITEST grant, all projects were driven by individual community concerns of particular schools and teachers for water quality in their localities. Curriculum was designed around local watersheds in various counties (Fayette, Woodford, Marion, Scott, Robertson, Madison, Grant, and Floyd counties). Professional Development for teachers and students was provided at summer workshops and lessons were conducted in classes on a myriad of topics including nature of science, experimental design, science communications, GPS and geospatial topics (GIS mapping and data analysis), stormwater runoff, watersheds, chemical and biological water quality indicators, riparian vegetation and invasive species, data collection at local streams, and analysis and presentation of data using GIS mapping. The funding through LFUCG Stormwater Initiative is much the same though concentrating on professional development of teachers in five Fayette County elementary and middle schools.

The results of these on-going Community Based Science projects include several hundreds of hours of in class lessons for students and teachers as well as several thousands of hours of student contact time in field trips to local streams and ponds for data collection, reflection, and analysis. Ongoing professional development through the

LFUCG Stormwater Initiative has included or will include basic properties of water, watersheds, chemical and biological indicators of water quality, riparian vegetation, bacterial contamination of water, stormwater runoff and retention, rain gardens, point and nonpoint source pollution, GPS and GIS instruction, and karst topography. The intention is for teachers to use lessons in their classrooms to engage students in authentic and relevant science activities.



THE EFFECTS OF PRESCRIBED FIRE ON AMPHIBIAN AND REPTILE  
DIVERSITY IN AN OAK-GRASSLAND RESTORATION AREA.

ROBERT KNOPP\* and HOWARD WHITEMAN

Department of Biological Sciences and Watershed Studies Institute  
Murray State University  
Murray, KY 42071.  
502-422-0450  
rknopp@murraystate.edu

Historically, natural wild fires often swept through forests and grasslands, reducing plant biomass and affecting surrounding faunal communities. Prescribed fire management is a frequent tool in habitat restoration, yet the effects of such management on herpetofauna need to be better understood, because herpetofauna are a significant but underappreciated component of forest communities. We predicted that species adapted to drier and warmer environments would be more abundant in fire-managed habitats, outcompeting and filling niches at a higher rate than water dependent species, due to higher light levels, lower leaf litter, and less coarse woody debris (CWD) in such areas. Our study focused on eight wildlife ponds within a restoration burn area and eight similar ponds in an adjacent non-restored forest within Land Between The Lakes National Recreation Area. All ponds were sampled using dip-nets and minnow traps during June-August 2011, and drift fences were checked daily for captured animals from September through October. Amphibian larvae were captured and identified to species, and all herpetofauna found at fences were recorded. Data analysis is ongoing and our preliminary results will be discussed.

## NOTES

[illegible]

RESULTS OF A DATA EVALUATION TO ESTABLISH PRIORITY  
REMEDATION AREAS FOR DRY WEATHER FECAL CONTAMINATION  
IN A KARST INFLUENCED WATERSHED

Steve Evans, Environmental Planner, Third Rock Consultants  
Stefanie Farrell, Environmental Engineer, Third Rock Consultants  
Demetria R Kimball, Environmental Inspector, LFUCG Division of Water Quality  
sevens@thirdrockconsultants.com

The goal of this study was to utilize a simple, cost effective means of identifying the land areas with the highest rate of sanitary sewer exfiltration to prioritize sanitary sewer investigations and point repairs. While wet weather problems including sanitary sewer overflows (SSOs) are generally well characterized by wastewater managers, sources of dry weather exfiltration are more difficult to identify, particularly in karst systems. This study was conducted in the Wolf Run watershed in Lexington, KY and analyzed stream flow and *E. coli* concentration data in conjunction with prior microbial source tracking assessments collected under low flow conditions in order to identify catchments with the highest incremental fecal load yields.

Two data sources were utilized in this analysis, each governed by an approved quality assurance project plan. A microbial source tracking study conducted in 2010 by the University of Kentucky Environmental Research and Training Laboratory (Brion et al 2011) was utilized to indicate the fecal load source. To calculate the fecal loading, dry weather *E. coli* sampling and stream flow measurements conducted under an EPA 319(h) grant for development of a Wolf Run watershed plan were utilized. *E. coli* samples were collected by Friends of Wolf Run and analyzed by the LFUCG Town Branch Laboratory and flow was measured by Third Rock Consultants.

The total loading and incremental loading were calculated in twelve catchment areas by utilizing the geometric mean of loading results from dry weather events and a simple spreadsheet model. In order to determine incremental yields, drainage areas were adjusted to account for karst flow.

As a result of this analysis, several areas within the Wolf Run watershed have emerged as priority areas to focus sanitary sewer remediation efforts. In order of priority, these areas include: 1) Wolf Run between Faircrest Drive and Lafayette Drive (W09), 2) Big Elm Tributary upstream of Harrodsburg Road (W11), and 3) Vaughn's Branch upstream of Tazwell Drive (W07). Correspondence between the microbial source tracking results and the highest loading sources indicates that human sewage is also the primary source of fecal pollution in the watershed.

As a result of this analysis, the LFUCG Division of Water Quality is conducting follow-up investigations, in addition to the remedial measures plan, to determine locations for point repair and remediation.

## NOTES

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# DEVELOPMENT OF IN-HOUSE METHODS FOR HIGH-THROUGHPUT DNA EXTRACTION

Kimberly L. Cook<sup>1</sup> and LorraBelle Hill<sup>2</sup>

(1) USDA-ARSAWMRU, Bowling Green, KY; kim.cook@ars.usda.gov; 270-781-2579

(2) Alabama A&M University, Huntsville, AL

Given the high-throughput nature of many current biological studies, in particular field-based or applied environmental studies, optimization of cost-effective, efficient methods for molecular analysis of large numbers of samples is a critical first step. Existing methods are either based on costly kits purchased from the biotech industry or are low-throughput, time consuming and/or not optimized for environmental analyses. Here we describe the development and optimization of a 96 well, high-throughput method for extraction of DNA from enrichment broths targeting pathogens and indicators. The DNA extraction method that is being developed is derived from classic methods which involve microbial cell lysis, deprotenation, alcohol precipitation, washing of nucleic acid extract and silica matrix-based DNA capture.

The evaluation of extraction methods was carried out using overnight soil enrichments from samples collected from an on-going study established to evaluate survival of pathogens in conventional or no-till fescue plots with applied poultry litter or dairy manure. Samples (0.3 mL) from each broth type or from pooled broth samples were used for analyses. DNA concentration, DNA purity, PCR inhibition and amplification of targeted populations (particularly the *Salmonella* sp. *ttr* gene which is required for tetrathionate respiration) were measured.

The baseline for comparison was the FastDNA<sup>®</sup> Spin Kit for soil (MP Biomedical, Solan OH). The developed methods were modified from three previously published methods Petric et al., 2011; Li et al, 2010; and Boyle and Lew, 1995. Methods used variations of SDS lysis [100mM Tris (pH 8.0), 100 mM EDTA (pH 8.0), 100mM NaCl, and 2% (w/v) SDS] in conjunction with deprotenation (3M sodium acetate), DNA cleanup/alcohol precipitation and DNA recovery (precipitation or silica matrix). DNA concentrations (Table 1) were compared for diverse methods. However, to obtain consistent results in 96 Well plates, the final method (fRPE) involved mechanical beating using the FastPrep BeadBeater but without beads, realizing a significant cost savings.

**Table 1. DNA Concentration per broth in ng/ul**

Broth <sup>a</sup>	Fast DNA	PLB1 <sup>b</sup>	PLB2 <sup>b</sup>	mPLB <sup>b</sup> (tubes)	mPLB <sup>b</sup> (96 wells)
<b>Bolton</b>	32.78 ± 9.10	14.54 ± 7.86	69.89 ± 23.14	57.75 ± 2.57	10.52 ± 0.59
<b>BPW</b>	77.69 ± 11.12	35.37 ± 5.95	49.54 ± 6.85	27.53 ± 14.96	13.10 ± 4.21
<b>RV10</b>	6.90 ± 1.85	45.86 ± 8.12	55.78 ± 25.18	43.08 ± 33.98	11.41 ± 4.32
<b>TTH</b>	72.26 ± 29.26	25.07 ± 0.66	90.84 ± 40.00	77.72 ± 44.39	12.73 ± 0.83
<b>UVM</b>	32.60 ± 13.43	17.14 ± 8.71	12.5 ± 10.92	12.5 ± 10.92	12.36 ± 3.01

<sup>a</sup> Broth indicates media used for enrichment of *C. jejuni* (Bolton), All Cells (BPW),

*Salmonella* (RV10 & TTH), *L. monocytogenes* (UVM)

<sup>b</sup> PLB or mPLB refers to modification of methods described by Petric, 2011; Li, 2010; Boyle, 1995

Values represent the average ± standard deviation of triplicate samples quantified by the NanoDrop 100 Spectrophotometer

Ultimately, the most significant factors in the method development were using a mechanical lysis and optimizing the type of silica matrix used to bind the extracted DNA (Table 2). The silica matrix binds DNA selectively in the presence of a chaotropic agent i.e. a chemical which disturbs the structure of water (Carter and Milton, 1993). A variety of chaotropic agents have been used for such purifications including sodium iodide (NaI), sodium perchlorate and guanidinium thiocyanate (GITC). Initial protocols utilized silica matrix resuspended in NaI but results were inconsistent, likely due to a slight change in the pH of NaI from 6.4 to more than 7.4. The binding of DNA to the silica is strongly pH dependent, above pH 7.5 binding is poor and rapidly becomes better below 7.5. We developed a HCl-based re-suspension solution for the glass milk (AGM) by combining 4M-6M solution of a chaotropic solution (NaI or GITC) with the silica solution brought to pH 2 with 30% HCl. In this way, pH is maintained between pH 6.0 and pH 7.4.

**Table 2. Evaluation of *Salmonella* concentration in enrichment broth using modifications of extraction methods**

Extraction method	Lysis Method	Silica Matrix	Chaotropic Agent	<i>Salmonella</i> Conc. (Cells g <sup>-1</sup> )	Method Notable
		Acidified	Agent		
Fast DNA Extractions	Beating w/Beads	Proprietary	Proprietary	0.15 ± 0.03 X 10 <sup>4</sup>	Standard Method
mPLB	Heat	No	NaI	4.79 ± 0.71 X 10 <sup>4</sup>	Best Method but inconsistent result
mPLB-2	Heat	No	NaI	1.77 ± 0.52 X 10 <sup>4</sup>	Lower Chaotropic Agent
mPLB-3	Heat	No	NaI	3.39 ± 0.44 X 10 <sup>4</sup>	Higher Chaotropic Agent
RPE-1	Heat	YES	NaI	2.64 ± 0.17 X 10 <sup>4</sup>	Acidified Silica
RPE-2	Beating w/Beads	YES	NaI	7.52 ± 1.02 X 10 <sup>4</sup>	Acidified, Beating & Added Beads
RPE-3	Beating no Beads	YES	NaI	9.55 ± 0.71 X 10 <sup>4</sup>	Acidified, Beating & No Beads
RPE-4	Beating no Beads	YES	GITC	4.11 ± 0.80 X 10 <sup>4</sup>	New Chaotropic Agent-More stable
<b>fRPE</b>	<b>Beating no Beads</b>	<b>YES</b>	<b>GITC</b>	<b>7.67 ± 0.32 X 10<sup>4</sup></b>	<b>Acidified, GITC, Beating &amp; No Beads</b>

This method is performed in a 96 well format using lab-based solutions for extraction and DNA binding. The high-throughput format permits preparation of up to 192 samples in a 4 hour time frame. By eliminating the use of purchased extraction solutions, extraction tubes and silica matrix, the cost per sample has been estimated to be as low at 10 cents.

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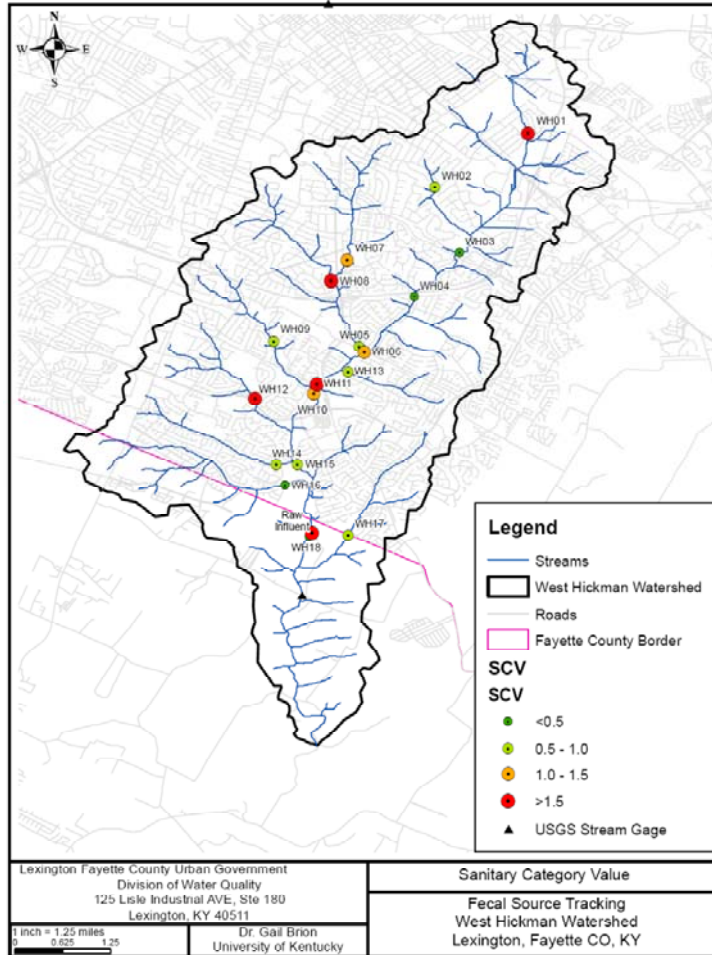
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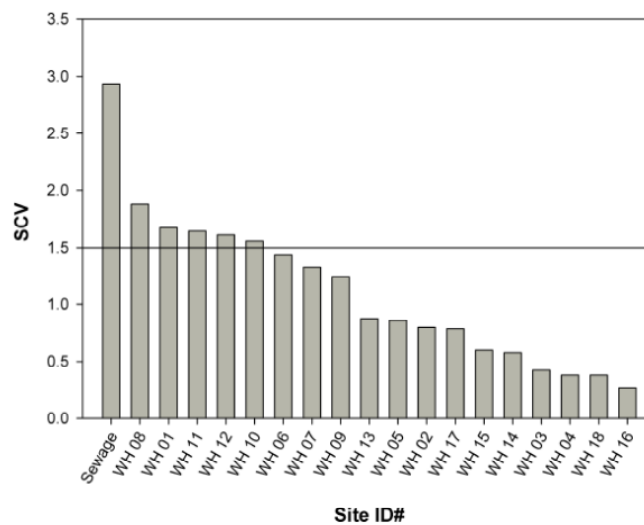
VALIDATION OF THE SANITARY CATEGORY VALUE (SCV) MODEL  
FOR THE IDENTIFICATION OF LEAKING SEWER LINES:  
A STUDY OF THE WEST HICKMAN WATERSHED OF LEXINGTON, KY

Gail Brion and Tricia Coakley  
859-257-6757  
Department of Civil Engineering, University of Kentucky  
Lexington, Kentucky 40506  
gbrion@engr.uky.edu; tcoakley@engr.uky.edu

A study of the West Hickman watershed was conducted to validate an approach for relative ranking of sewage impacted locations within Lexington's watersheds for future remediation. A simple modeling system was created by researchers at the University of Kentucky and evaluated in a prior Lexington Fayette Urban County Government (LFUCG) sponsored project in the Wolf Run Watershed. The approach included indicators of fecal load, age, and source as well as a sampling plan that included a wide spatial and temporal range. This system was applicable for ranking regions within the watershed with respects to the degree of sewage intrusion based upon a Sanitary Category Value (SCV). The SCV could be used to pinpoint hotspots of sewage intrusion into the watershed and prioritize areas for remediation. The same approach and modeling system were applied to water quality samples obtained from the West Hickman Watershed under dry weather conditions in a recent study supported by LFUCG. Samples were collected by the employees of Third Rock Consulting from eighteen locations on four dates between August and October of 2011. The samples were analyzed at the ERTL facility at UK for viable *E.coli* bacteria, the ratio of atypical colonies (AC) to total coliforms (TC), and the concentrations of general and human specific *Bacteriodes* DNA markers. The results from each indicator analysis were then combined to generate a single SCV for each sample location. The overall results of this study indicate that while West Hickman does not have sites that are as severely impacted by fresh human sewage as were found in Wolf Run, there are some sample sites that show the continuous presence of human sewage. These hotspots are prioritized to receive further investigation and determination of source so that remediation can be undertaken and these potential sources of disease eliminated from the watershed. As was shown previously in the Wolf Run watershed, the SCV model approach provided identification of the highest priority sites and relative ranking of all sites in the West Hickman watershed without the need for more expensive engineering efforts.



**Average Sanitary Category Values for West Hickman Watershed under Dry Weather Conditions**





COMPARISON OF SOIL-MOISTURE BASED IRRIGATION SCHEDULING  
TO POTENTIAL EVAPOTRANSPIRATION  
IN TOMATO GROWN USING PLASTIC MULCH

Susmitha Nambuthiri and Timothy Coolong  
Department of Horticulture, University of Kentucky, Lexington, KY 40546  
(859) 257-3374  
ssnamb2@uky.edu, timcoolong@uky.edu

Richard Warner  
Dept of Biosystems and Agricultural Engineering, UK, Lexington, KY 40546  
(859)-257-8803 x 217  
rwarner@bae.uky.edu

Irrigation scheduling has traditionally been weather or soil based. In weather-based scheduling, the decision to irrigate relies on the soil water balance. The water balance technique involves determining changes in soil moisture over time based on estimating evapotranspiration (Et) adjusted with a crop coefficient (Penman, 1948). This method takes environmental variables into account along with crop coefficients that are adjusted for growth stage and canopy coverage (Hartzt, 1996). However, variability in production systems has made Et-based irrigations less common in vegetable crop production. (Amayreh and Al-Abed, 2005; Burman et al., 1980). Soil-based methods are often employed to manage irrigations in vegetable production. Typically these methods involve maintaining soil moisture between predetermined thresholds regardless of weather and crop conditions. A purpose of this trial was to determine water usage between several soil-moisture based irrigation regimes and potential evapotranspiration in plasticulture-grown tomatoes.

This study was conducted during 2009 and 2010 at the University of Kentucky Horticulture Research Farm in Lexington, KY. Tomato (*Lycopersicon esculentum*) 'Mountain Fresh' was grown using standard procedures for plasticulture production in KY (Coolong et al., 2009a). Automated irrigation was managed using paired switching tensiometers (model RA 12-inch; Irrrometer, Riverside, CA). In paired treatments, one tensiometer functioned to turn on irrigation while the other turned it off. Tensiometers were placed approximately 20 cm from the tomato plants and 10cm from the edge of the raised beds, at a depth of 20cm from the upper surface of the bed. On/off set points for the four, two-tensiometer treatments were as follows: on/off -30/-10, -30/-25, -45/-10, -45/-40 kPa. These set points were based on previously reported thresholds (Coolong et al., 2009b; Wang et al., 2007). The frequency and duration of the automated and manual irrigation events were recorded with data loggers (Hobo U9 State Data Logger; Onset, Cape Cod, MA). There were four replications of irrigation treatments. Treatment plots consisted of 20 plants (measurements were taken on 16 plants in the center of each plot) arranged in a completely randomized design for a total of 20 experimental plots. Weather data were obtained from an on-farm weather station that recorded environmental

variables every minute and provided hourly averages [Kentucky Mesonet, Fayette County Station, Lexington, KY (University of Kentucky, 2011)].

Despite hotter and drier growing conditions, water usage was generally lower in 2010 compared to 2009. The -45/-40 kPa treatment used the least amount of water in both years with 98,496 gallons/acre and 85,147 gallons per acre in 2009 and 2010, respectively. The soil-moisture based treatment using the most water differed from the -30/-25 kPa treatment in 2009 to the -30/-10 kPa treatment in 2010. Nonetheless, all soil-moisture based treatments used substantially less water than estimated potential Et. In 2009 potential Et was determined to be 353,997 gallons/acre using FAO-based crop coefficients (Allen et al., 1998) for field-grown tomato or 235,367 gallons/acre using a crop coefficient determined for plasticulture-grown tomato (Amayreh and Al-Abed, 2005). Due to differences in spacing, soil coverage and localized drip irrigation the potential Et calculated using FAO crop coefficients were always greater than those using coefficients developed specifically for plasticulture production. In 2010, conditions were drier and hotter and potential Et was determined to be 422,136 and 638,578 gallons/per acre for plasticulture-based and FAO crop coefficients, respectively. Total marketable yields among irrigation treatments were not significantly different in 2009, but did differ in 2010; however, there were no clear trends between yield and water use in 2010. Yields were commercially satisfactory in both years suggesting that soil moisture was not limiting production. These results suggest that soil-moisture based irrigation can significantly reduce water use compared to using Et-based methods. In addition, for plasticulture-grown tomatoes, Et-based methods may significantly overestimate water usage as differences in microclimate and production methods may not be accounted for in calculations using standardized crop coefficients.

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# THE POTENTIAL FOR USING A P LOSS MODEL TO IMPROVE THE ACCURACY OF THE KENTUCKY PHOSPHORUS INDEX

Carl H. Bolster  
Animal Waste Management Research Unit, USDA-ARS  
Bowling Green, KY 42104  
Phone: 270-781-2632  
E-mail: carl.bolster@ars.usda.gov

**Introduction:** The phosphorus (P) Index is an assessment tool developed to identify fields which are most vulnerable to P loss by accounting for the major source and transport factors controlling P movement in the environment. The Kentucky P Index was developed over 10 years ago, and since its inception, a significant amount of research investigating the factors governing P loss at the field scale has been published. The KY P Index, however, has not been updated to stay current with the literature. A recent analysis by Bolster (2011) showed that several limitations exist with the Index, including how each factor in the Index is weighted, the lack of terms to account for planned P application rates, and the use of land cover and field slope as surrogates for erosion rather than erosion rates as derived from RUSLE. Furthermore, a recent comparison between measured P runoff collected from sites in North Carolina and Georgia and estimates of P risk obtained with 12 southern P Indices showed that the KY P Index provided some of the poorest estimates of P loss risk of all the P Indices tested. These studies highlight the need to update and revise the KY P Index to better reflect the current state of the science.

Ideally, measured edge-of-field P loss data should be used to update and refine a P index. However, such data are lacking in many states and this is particularly true for Kentucky. When sufficient data are unavailable, an alternative approach to updating and improving a P Index is to use estimates of P loss generated from a validated P loss model to help guide index revision. In the current study, this approach to P Index revision is evaluated using the Pennsylvania P Index, which is one of the more well-developed P indices in the U.S. and has served as a template in the development of other P indices, with the goal of demonstrating that this approach should be considered for updating and revising the KY P Index.

**Methods:** P loss data were generated for a wide range of field and land management conditions using the Annual P Loss Estimator (APLE) P loss model (Vadas et al. 2009). The P loss data were then fit with the PA P Index by using least squares regression to adjust the weights on each factor in the index to obtain the best fit to the model-generated data. Estimates of P loss risk were then calculated for a variety of fields across a range of physiographic and climatic regions in the U.S. using the existing and modified versions of the PA P Index and compared with measured edge-of-field P loss data. Correlations between the measured P loss data set and values of the original and modified PA P Indices were evaluated.

**Results:** Fitting the PA P Index to the APLE-generated data resulted in a noticeable reduction in the amount of scatter between P Index values and model-generated P loss when compared with the original Index. The weights obtained by fitting the APLE-generated P loss data were significantly different from the weights of the original PA P Index. More importantly, the relative magnitudes of the weights for the modified Index were drastically different from the original Index. For instance, in the original PA P Index, weights for runoff, sediment loss, applied manure, and applied fertilizer are all set to one and the weight for STP is 0.2. The weights for the modified version of the PA P Index, however, varied by a factor of over 20. The biggest difference in the relative magnitudes of the weights is in how particulate P loss is weighted. With the original Index, P loss from runoff and erosion are equally weighted. The fitted weight for the erosion component of the modified Index, however, was an order-of-magnitude greater than the fitted weight for dissolved runoff P loss from STP.

Using the weights obtained from fitting the APLE-generated data noticeably increased the correlation between P index predictions and the measured P loss data set. For instance, using the modified P index increased  $r^2$  from 0.19 to 0.36 for the untransformed data and from 0.52 to 0.65 for the log-transformed data. Moreover, the root mean square error, mean absolute error, and mean absolute percent error were all significantly lower for the modified PA P index compared with the original PA P index.

**Summary:** The significant improvement in the modified version of the PA P index using the fitted weights demonstrates the critical role that proper weighting plays on P index accuracy. In the current KY P Index, index weights were based on the professional judgment of the technical specialists who developed the 590 Standard for KY (NRCS 2001). In this study a simple method for obtaining index weights that are consistent with a validated P loss model is demonstrated using the PA P Index as an example. An additional advantage to this approach is that the resulting P Index is capable of generating actual estimates of P loss (i.e. loads) rather than a relative risk rating. This is an important consideration given the recent emphasis by USEPA for states to develop numeric water quality standards for lakes and streams. Given that USDA-NRCS is requiring that each state evaluate the accuracy of their P index, the method demonstrated in this study should be considered when making needed revisions to the KY P Index.

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ADDITIVE STATE SPACE MODEL – A PROMISING APPROACH TO  
WATER-QUALITY-RELATED TREATMENT EXPERIMENTS IN  
HETEROGENEOUS LANDSCAPES

Ole Wendroth  
University of Kentucky – College of Agriculture  
Department of Plant & Soil Sciences  
Ag. Sci. North N-122M  
Lexington, KY 40536-0312  
Phone: (859) 257-4768  
E-mail: owendroth@uky.edu

Inherent soil spatial variability complicates understanding of hydrological, soil and plant-related processes in agriculturally used ecosystems. This variability is often times considered as a severe obstacle especially when treatments have to be imposed in an area of interest that is known to be affected by underlying spatial trends. In those cases, randomization and blocking of treatments does not necessarily result in the expected compensation of soil variability or spatial trends of soil properties across the landscape. The objective of this contribution is to introduce an experimental approach to study field-scale solute leaching behavior as affected by rainfall amount, intensity and application time delay in a variable landscape of Kentucky. The experimental approach is also applied to a nitrogen fertilizer experiment in a farmer's field that is known for its considerable spatial variability causing the crop response to vary across the landscape. In this case, a unique fertilizer-yield-response function would be inappropriate. In both field studies, treatments were not randomly arranged but laid out in a systematic sine-oidal design. The concept of this design is based on the fact that the scale of treatment application differs from that of underlying field variability. An additive state-space model approach has been adapted from economic time series modeling. It decomposes small-scale variability caused in our studies by treatments of either rainfall scenarios in one case or fertilizer application rate in the other case. The large-scale component manifests the underlying trend caused by different factors that remain unknown or are known to some extent. In case of the leaching experiment, different rainfall characteristics were varied in the experiment across different scales. The new additive state-space approach was able to separate small-scale from large-scale variation components, the latter being in our case the influence of rainfall amount and intensity. Once the different scales of variation were identified, the large-scale behavior was described in an autoregressive model. In case of the leaching experiment, the auxiliary variables were amount and intensity of rainfall application, and in case of the nitrogen treatment study, landscape topography, such as elevation, and soil clay content were most helpful to explain the

varying response of the crop yield to nitrogen applied across the field. In the presentation, both experiments will be presented in detail and their major outcomes, followed by a description of the statistical analysis. The results of this contribution are relevant for all those who study hydrologic, vadose zone and crop processes at the field- and landscape-scale. This study shows how to impose treatment experiments in a non-random but systematic design in variable landscapes in order to improve water and environmental quality, efficiency of nitrogen fertilizers, and management of water resources and field crops. At the same time, inherent soil variability does no longer have to be considered as an obstacle, but as an opportunity.

## DEVELOPMENT AND APPLICATION OF NUMERIC INTERPRETATIONS OF KENTUCKY'S NARRATIVE WATER QUALITY STANDARDS FOR NUTRIENTS

Lara Panayotoff  
Kentucky Division of Water  
200 Fair Oaks Lane  
Frankfort, KY 40601  
502-564-3410  
lara.panayotoff@ky.gov

Excess nutrients are a significant cause of water quality impairments to surface waters in Kentucky. Excess nutrients can affect water quality and uses of lakes and streams through stimulation of plant and algal growth which can result in low or widely fluctuating dissolved oxygen, pH, altered habitat for aquatic life, reduced biological integrity of aquatic communities, taste and odor problems in drinking water systems, and aesthetically undesirable accumulations of algae. These potential problems from nutrient-related causes are addressed in various sections of Kentucky's water quality criteria. In the course of surface water quality monitoring, field observations, measurements and biological surveys identify cases where these criteria are exceeded, resulting in an assessment that the waterbody is not supporting aquatic life or recreational uses.

Waterbody impairments from nutrient-related causes are addressed by water resource management programs such as the Total Maximum Daily Load (TMDL) and Nonpoint Source Pollution programs, through TMDL calculations and watershed-based plans. Both programs have a goal of returning the waterbody to meeting water quality standards and fully supporting the uses. These programs require quantifiable target concentrations for the pollutant in order to develop allowable loads and calculate the needed load reductions. Since many of the water quality criteria related to nutrients are narrative and not numeric, these narrative criteria must be translated into numeric interpretations. The Kentucky Division of Water (DOW) has recently outlined a process for developing numeric interpretations for TMDL analysis and watershed-based plans involving nutrients. While there are important differences in the function of targets for these two purposes, the general process is similar. Multiple sources of information are drawn upon to derive one or more targets that are appropriate for the watershed characteristics and the specific nature of the observed impairment(s). The first category of information comprises empirical data from similar streams that show the relationship between nutrient indicators and indicators of impairment, preferably pointing to a concentration or range above which impairment is likely to occur. The second category of information employs summary statistics describing the range of concentrations observed in similar streams that have been observed to fully support the use (i.e., "reference sites"). The third category of information consists of literature values such as classification schemes, models, or other published guidelines that are relevant to the specific impairments identified and which have been derived from comparable watersheds. Multiple candidate targets produced from these three categories are weighed and a final target is selected.

This general approach to developing numeric interpretations has been used to provide initial target concentrations for a TMDL model under development for nutrients in Floyds Fork (Jefferson, Oldham, Shelby, Bullitt, and nearby counties). For this watershed, stream size was judged to be an important factor potentially influencing the response of aquatic life and benthic algae to nutrient loadings. Targets were selected (total phosphorus and total nitrogen) for three stream-size classes. Targets take two forms: a conservative target where the model can allow an exceedence of the target every three years and a maximum target that should not be exceeded in the water quality model. Follow-up monitoring in 2012 will be conducted to validate or refine these targets before finalizing the allowable loads.

**Floyds Fork TMDL Draft total nitrogen and total phosphorus targets\***

Size category	TP target 3 yr ex	TP target max	TN target 3 yr ex	TN target max
Headwater (<5 sq mi)	0.09	0.12	0.70	1.0
Wadeable (5-100 sq mi)	0.15	0.25	1.1	1.6
Transitional/Boatable (>100 sq mi)	0.20	0.66	2.2	2.4

\*In headwater sections of the watershed, the target is to be applied as an annual geometric mean. In wadeable and transitional/boatable sections, the target is to be applied as a growing season (April-October) geometric mean. In all sections, the lower target is not to be exceeded more than once in every three years, and the maximum is never to be exceeded, each of these as an annual or growing season geometric mean.

Numeric interpretations also are being developed by DOW in support of watershed based plans (WBPs). Targets serve multiple functions in WBPs. First, a set of screening benchmarks is helpful in the process of reviewing early phase monitoring data in order to identify priority sub-watersheds for the more focused monitoring needed to estimate pollutant loads. Second, after review and possible refinement, the targets for select indicators can serve as analytical endpoints for determining load reductions. Finally, targets can be used for post-implementation success monitoring as an indicator of when to re-examine recovery of the uses. Benchmarks have been developed for two WBPs to date (January 2012) with more in review. Pending input and feedback from the WBP developers, these benchmarks will serve as target concentrations for developing load reductions in the plans.

**Watershed-Based Plan Benchmark Recommendations**

Triplett Creek, Rowan County		Lower Howards Creek, Clark County	
Total P	0.02 mg/L	Total P	0.25 mg/L
TKN	0.50 mg/L	TKN	0.50 mg/L
Nitrate-Nitrite-N	0.40 mg/L	Nitrate-Nitrite-N	2.0 mg/L
Total N	0.65 mg/L	Total N	2.5 mg/L



## ARSENIC REMOVAL IN REACTOR SYSTEMS

Aniruddha Dastidar<sup>1</sup> and Y.T. Wang<sup>2</sup>

<sup>1</sup>Watershed Management Branch, Division of Water  
Frankfort, KY 40601  
502-564-3410 ext 4952  
Andy.Dastidar@ky.gov

<sup>2</sup>Professor, Dept Civil Engineering  
University of Kentucky

The potential application of a biochemical process for achieving near complete removal of arsenic in the wastewater stream was investigated in one-stage and two stage reactor systems. The process involved the coupling of biological oxidation of As (III) to As (V), and the subsequent adsorption of As (V) by Activated Alumina (AA). The chemoautotrophic *Thiomonas arsenivorans* strain b6 was used for the oxidation of As (III) to As (V). The one-stage reactor process was operated under two influent As (III) concentrations (60 mg/L and 100 mg/L) and a constant hydraulic retention time (HRT) of 1.0 day for 12, and 6 days, respectively. The pattern of arsenic removal was very similar under both operating conditions. The two-stage reactor system was operated under a very high influent As (III) concentration of 500 mg/L and HRT of 1 day. A near complete removal of arsenic was achieved at 10 days in the two stage reactor process. However, the overall performance of both reactor systems may have been limited due to various operating parameters and interference from several chemical species competing for the same adsorption site on AA.

## NOTES

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## TRENDS IN WATER QUALITY ISSUES FOR APPALACHIAN MINING

W. Blaine Early, III  
Stites & Harbison, PLLC, 250 W. Main Street, Suite 2300, Lexington, Kentucky 40507  
859-226-2284  
bearly@stites.com

Steven Gardner  
Douglas Mynear  
ECSI, LLC, 340 S. Broadway, Suite 200, Lexington, Kentucky 40508  
jsgardner@engrservices.com  
dmynear@engrservices.com

Water quality issues continue to impact coal mining operations in Appalachia as operators attempt to obtain permits for pollutant discharge or hollow fills. Diverse groups have assessed the long-term impacts of mining and reclamation efforts on water quality. This presentation examines recent research reports and ongoing studies of cumulative hydrologic impact of surface mining in Appalachia. Interpretation of these studies may inform decisions by regulatory authorities including the U. S. Army Corps of Engineers, the U. S. Environmental Protection Agency, and the Kentucky Division of Water as they evaluate requests for permits.

Well-publicized studies, such as those by Gregory Pond and others, have raised questions about the long-term impact of Appalachian mining on aquatic life in mountain streams. Recent studies published in 2011 suggest additional evidence of the impacts of mining. These new studies include those by Melissa M. Ahern, et al., 2011, The association between mountaintop mining and birth defects among live births in central Appalachia, 1996-2003, *Environmental Research* 111, 838 – 846; and Ty Lindberg, et al., 2011, Cumulative impacts of mountaintop mining on an Appalachian watershed, *PNAS*, see [www.pnas.org/cgi/doi/10.1073/pnas.1112381108](http://www.pnas.org/cgi/doi/10.1073/pnas.1112381108). These are not the only sources of new information, however, because both operators and regulators continue to conduct field studies to gather data used in cumulative hydrologic impact assessments (CHIA). Comparing the results of these additional studies suggests that the impact of mining and related activities varies among watersheds.

These water quality issues inform critical decisions on water discharge permits issued under Section 402 of the Clean Water Act and dredge and fill permits issued under Section 404 of the Clean Water Act. In connection with evaluation of these permits, EPA and the Corps entered into a Memorandum of Understanding to conduct “Enhanced Surface Coal Mining Pending Permit Coordination Procedures” (“Enhanced Coordination Procedures”). The EPA also issued a Detailed Guidance: Improving EPA Review of Appalachian Surface Coal Mining Operations Under the Clean Water Act, National Environmental Policy Act and the Environmental Justice Executive Order (“Detailed Guidance”).

Several groups independently filed suit against EPA to challenge EPA's oversight of coal-related water permits under the Enhanced Coordination Procedures and the Detailed Guidance. The different suits were consolidated into one now pending in the U.S. District Court, Washington, D.C. In October 2011 the U. S. District Court struck down policies and procedures adopted by the EPA Corps regarding dredge and fill permits required under the Clean Water Act. National Mining Association v. Lisa Jackson, No. 10-CV-1220 (D. D.C. Oct. 6, 2011). The court ruled that the EPA had "exceeded the statutory authority conferred upon it by the Clean Water Act" and that the agencies had ignored the proper "notice and comment rulemaking requirements" of the Administrative Procedures Act. These consolidated cases will yield at least one more major decision regarding EPA's guidelines for review and requirements for water discharge permits for coal mining operations (the Detailed Guidance).

It is important to note that the issue before the court was not whether the policies and procedures were warranted by the facts about the environmental impacts of mining, and the court did not suggest that similar policies and procedures, if adopted according to statutes and procedural rules, would not be upheld. Therefore, it is critical to future regulatory decisions, whether in rulemaking or in individual permit decisions, that the breadth and complexity of water quality data be fully evaluated.

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# AGRICULTURE PRODUCER RESPONSES TO GOVERNMENT-FUNDED CONSERVATION PROGRAMS TO ADDRESS WATER QUALITY

Wuyang Hu, Pedro da Costa, Jack Schieffer, and Angelos Pagoulatos

Department of Agricultural Economics

University of Kentucky

313 C. E. Barnhart Building

Lexington, KY 40546

859.257.7271

wuyang.hu@uky.edu

## **Objectives**

The Kentucky Division of Water 2004 Kentucky Pollutant Discharge Elimination System (KPDES) Report to Congress on Water Quality (305[b] Report) shows that there are 1477.2 river miles within the Kentucky River Watershed affected by agricultural sources of discharge (nonpoint source—NPS). In order to mitigate the pollution in U.S. waterways including the Kentucky River Watershed, U.S. government conservation programs provide financial incentives for farmers' participation in voluntary pollution control. These programs are also commonly referred to as cost-share programs. Information about the adoption of these programs and best management practices (BMPs) will be important to the achievement of more stringent standards and/or further cost reductions in water quality improvements. Several studies have found that in general, higher levels of education attainment and higher cost-share percentages offered for each BMP correlate with the higher rates of adoption (Paudel et al., 2008; Suter et al., 2008). Higher cost-share percentages offered for BMPs may be one solution for additional adoption of conservation practices. In this study, the adoption of public conservation programs within the Kentucky River Watershed is examined.

## **Procedures**

Data used in this study come from two sources: secondary data collected through various sources of publicly available databases and primary data collected by a producer surveys conducted by the researchers. In the Kentucky River Watershed, there are three main conservation programs: EQIP (Environmental Quality Incentives Program), WHIP (Wildlife Habitat Incentives Program), and CRP (Conservation Research Program). All three programs are administered by the National Resources Conservation Service (NRCS) under the USDA. Information about adoption of these cost-share programs at the county level is available from the NRCS. In addition to the secondary data, the research team conducted a survey to collect producers' BMP practices, farm characteristics, farm operator characteristics, as well as producers' willingness to consider additional BMPs given additional cost incentives. Producers were identified according to their residence county. A system of three fixed-effects regressions can be performed to analyze factors contributing to producers' adoption of conservation programs. The dependent variables of the system of three equations were the amount of cost share incentives received by each farm. The dependent variables included farm and operator characteristics as well as

demographic nature of the various counties producers reside. Since the incentives producers receive were truncated at below at zero. A generalized Tobit model was adopted to estimate all three equations (one equation for each program) simultaneously while considering the fixed effects of producers.

## **Results**

Results generated so far show that the average numbers of farms per county and average farm size per county of the study region have a positive relationship with participation in the CRP. Holding all other factors constant, a county with one additional farm within its border is likely to receive \$44.80 more in CRP program payment. This is an expected result as the payment is awarded to a specific farm. The larger number farms indicate larger number of candidates to receive the payment holding other factors unchanged. In addition to the number of farms, holding all other independent variables fixed, if the average farm size of a farm increases by one acre, the CRP payment is projected to increase by \$300.92 per year. Thus, counties with more farms and larger farms tend to collect more CRP incentives. Land use type is found to be insignificant for CRP participation. The coefficient estimates for the EQIP and WHIP programs did not show as many significant results as those used to explain CRP. Results also show that farm operators' characteristics may have significant impact on their decisions to participate in government cost share programs.

## **Summary**

The voluntary nature of farmer and landowner participation in conservation programs requires studying the factors that may lead to this participation. Based on the findings from the literature, this study tested the relationships between participation in U.S. government cost share programs and a number of farm and farm operator characteristics in the Kentucky River watershed. Results show that counties with more farms and larger farms will probably have more participation in these programs. Adoption and funding could depend on land characteristics of individual plots of land such as slope and vicinity to water. Although this study comes from the U.S., it also offers an example for other countries or regions to conduct a similar research. In many developing countries, the tension between agriculture and the environment is often a protruding issue facing policy makers. For these countries, how to use an incentive-based program to mitigate the problem and how constituents may respond to such a program can be a discussion involving the experience from many countries in the world.

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# ABATEMENT COSTS FOR AGRICULTURAL NON-POINT SOURCE POLLUTERS

Zheng Liu, Jack Schieffer, Wuyang Hu, and Angelos Pagoulatos  
Department of Agricultural Economics  
University of Kentucky  
405 C. E. Barnhart Building  
Lexington, KY 40546  
859.257.7246  
jack.schieffer@uky.edu

This research estimates the costs of implementing riparian buffer strips on agricultural land in the Kentucky River watershed. These cost estimates are used in analyzing the feasibility of a water quality trading program in that watershed.

## **Background**

Water quality trading (WQT) programs are advocated as an important means to cost-effectively pursue water quality goals (USEPA 2003) and have been introduced in several states (Breetz et al 2004). Although agricultural non-point source (NPS) polluters are generally exempt from federal regulation, some trading programs allow point source (PS) polluters to meet their requirements by purchasing offset credits that reflect reductions in NPS discharges to the same waters (USEPA 2004).

The inclusion of agriculture in a trading program offers two potential benefits. First, since PS pollution is heavily regulated while agricultural NPS pollution is not, significant differences in marginal abatement costs can exist and the inclusion of agriculture can lower the overall expense of achieving water quality levels. Second, water quality targets under the Clean Water Act have not been met in many areas, and a growing share of such impairment is attributed to agricultural runoff (USEPA 2002). Meeting these targets will likely require reducing the impacts of agricultural runoff, and the use of offset credits in a WQT program is a politically feasible approach.

In a WQT setting, agricultural producers receive offset credits, which they can sell to PS polluters, when they implement best management practices (BMPs) that reduce nutrient loads. Producers are expected to undertake such BMPs when the value of the offset credits is sufficiently lower than the BMP cost. Among available BMPs, riparian buffer strips have proven effective in mitigating the movement of nutrients into surface waters (Qiu et al 2006), so estimates of riparian buffer costs would be useful in setting WQT policy.

## **Methods and Data**

We select six counties within the watershed that are characterized by a high proportion of nutrient-impaired waterways and for which a total maximum daily load (TMDL) of pollutants is approved or under development. These characteristics indicate that NPS offset credits might be in demand if a WQT program were implemented.

To estimate costs, we adapt the methodology used by Roberts et al (2009). Potential buffer strip areas are geographically located and their land uses are identified using National Land Cover Data and ArcGIS software. The cost of riparian buffers on cropland includes the opportunity cost of forgone production, as well as the costs of establishing and maintaining the buffer strips. Forgone production returns are determined from cropping practices and soil fertility, using spatially disaggregated data from the Web Soil Survey Database. The cost of riparian buffers on pasture land is derived from average rental rates and the cost of exclusion (fencing), as well as establishment and maintenance expenses. These costs are aggregated to form a supply curve of the buffer strip area that would be supplied at various prices.

### **Discussion**

The results indicate that land currently used for pasture and hay production, as opposed to row crops, is the most important factor in potential agricultural participation in a WQT program. Pasture and hay land accounts for the vast majority of potential riparian buffer area and also possesses much lower opportunity costs. Annualized costs for an acre of riparian buffer are estimated to range from approximately \$100/acre to \$600/acre and are highly sensitive to the prices of agricultural commodities.

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# POINT SOURCE POLLUTERS IN THE KENTUCKY RIVER WATERSHED AND THE POTENTIAL FOR WATER QUALITY TRADING

Ron Childress, Jack Schieffer, Wuyang Hu, Angelos Pagoulatos

Department of Agricultural Economics

University of Kentucky

405 C. E. Barnhart Building

Lexington, KY 40546

859-257-7246

ronald.childress@uky.edu; jack.schieffer@uky.edu

This research provides a profile of point-source (PS) polluters in the Kentucky River watershed. To analyze the feasibility of a water quality trading (WQT) program, the characteristics of the watershed's PS are compared with factors believed to encourage the success of such a program.

## **Background**

Since the enactment of the 1972 Clean Water Act (CWA), point-source polluters (e.g., municipal wastewater treatment plants) have been required to obtain permits and comply with effluent restrictions under the National Pollutant Discharge Elimination System (NPDES). Although significant progress has been made, substantial challenges remain. Reports indicate that up to 64% of assessed surface water bodies remain impaired, unable to support their designated uses (EPA, 2009). The Environmental Protection Agency (EPA), charged with administering regulations under the CWA, supports the use of water quality trading (WQT) programs as a means to address current water quality problems (EPA, 2003).

It is widely held that the marginal abatement costs are lower for non-point source (NPS) polluters than for the heavily regulated PS polluters, so that WQT has the potential to significantly lower the costs of achieving a given level of water quality (Faeth, 2000). However, cost-reduction can occur even when trading takes place among PS with heterogeneous cost structures (e.g., due to differences in age or type of equipment, economies of scale, nature of influents) without participation by NPS. WQT programs also have the potential to increase flexibility and availability of different options for improving water quality and to encourage innovation in related technology. Similar programs related to control of air quality have enjoyed substantial success (Stavins, 1998).

## **Data and Methodology**

The Kentucky Division of Water (KDOW) provided us with PS data regarding NPDES permits and compliance. We build upon the methodologies of Roberts, et al (2008), Kieser & Associates (2004), and Rowles (2005) to delineate potential WQT markets and analyze PS characteristics. We investigate five major components for a successful WTQ

market: environmental suitability, availability of participants, economic incentives, regulatory incentives, geospatial orientation. Particular attention is paid to characteristics related to the objectives and requirements of WQT specified by EPA policy (EPA, 2003). Thus, we focus on nutrient-related impairments, examine PS locations relative to potential NPS participants, analyze potential trading areas corresponding to receiving waters and TMDL boundaries, and allow for non-degradation constraints for individual segments. We also examine alternative regulatory scenarios, to compare trading feasibility under different conditions. In addition, we use GIS software to examine the geospatial connections among PS, NPS, and impaired waters.

## **Results**

Current findings show that PS are non-compliant with total nitrogen as ammonia (TNA) and total phosphorus (TP) requirements in their permits throughout the year, creating potential for water quality trading for these two nutrients on a monthly level. Stricter regulation of TP and TNA point sources, as states try to comply with water quality-based standards, will create more potential for WQT as a mechanism for decreasing the costs of such compliance.

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# POINT SOURCE ABATEMENT COSTS AND PREFERENCES FOR TRADING MARKET MECHANISMS IN THE KENTUCKY RIVER WATERSHED

Andrew McLaughlin, Wuyang Hu, Jack Schieffer, and Angelos Pagoulatos

Department of Agricultural Economics

University of Kentucky

337 C. E. Barnhart Building

Lexington, KY 40546

859-257-7272

Andrew.mclaughlin@uky.edu

## **Objectives**

This study aims to understand the current cost structure and preferences for market structures among municipal sewage treatment facilities along the Kentucky River basin in the context of a potential water quality trading (WQT) market. These facilities are Point Source polluters (PS) and may soon be facing stricter regulations in terms of targeted allocated TMDLs which will be set in place by the National Pollutant Discharge Elimination System (NPDES). In order to avoid steep penalties, various PS may need to invest in new equipment to reduce their levels of pollution (Breetz et al. 2005). The first objective in our study is to find out the methods these facilities may be implementing to meet the new requirements, either in the form of purchasing new equipment or by improving the biological/chemical treatment processes. The second goal is to understand the costs, both currently and in the past, for controlling water quality in the Kentucky River. Thirdly, this study attempts to gain an understanding of what market trading mechanisms, given their different implementation schemes and market implications, PS would prefer to take part in. Knowing the methodology used to control water quality, the costs associated, and the preferred market trading mechanism will have direct contribution to assessing the feasibility of WQT.

## **Background**

In Kentucky, The NPDES is establishing a permit program that will be overseen by the Kentucky Department of Water (KDOW) that will limit the allowable amount of pollutants in wastewater. The WQT market is made up of buyers (over-polluters: typically PS) and sellers (underpolluters: typically NPS) who may trade pollution rights. Failure to meet the requirements for a target TMDL will be the driving force behind demand for additional water quality credits by PS. So long as the maximum cost for attaining an additional credit is less than the minimum marginal cost of implementing new technologies, there will be a net gain for PS participating in WQT (USEPA 2004).

In the past, multiple studies have addressed issues involving PS in the context of WQT. However, none has examined PS preferences for potential trading mechanisms. Given the different transaction costs or organizational implications of various trading schemes, PS preferences will likely contribute to the success of WQT.

## **Data and Methods**

This study uses a survey conducted among PS in the Kentucky River watershed. PS addresses and contact information were obtained from the KYDOW. The survey included three main sections. The first section of the survey was designed to get a profile of PS such as their size and service history. The second section of the survey asked for information on the current and historical technology used for water quality control and the associated costs. The third and final section of the survey gathered PS preferences between four potential market mechanisms: Seller/Buyer Negotiations, Government Facilitation, Market Exchange, and lastly Sole-Source Offset. Detailed information about these market mechanisms are presented in the survey using language pre-tested by PS.

## **Results**

The survey is currently in its final stage of completion (completion in four weeks is expected). Preliminary results indicate that in the Kentucky River Watershed, roughly one third of all PS are considered by the EPA as major sources. Depending on the size and location of the PS, they use different pollution reduction methods and the costs involved in implementing these practices vary greatly between facilities. Opinions about preferred market trading mechanisms differ across facilities and even across different managerial personnel within the same facility. These results suggest that there is much more to be understood about PS including their role and preferences in a potential WQT market. Our study will contribute to this discussion.

## **Discussion**

Our study adds to the discussion of establishing tradable water markets to reduce water pollution. Pollutants entering the Kentucky River watershed are discharged into the larger Ohio River watershed which will inevitably contribute to the formation of the hypoxic zone in the Northern Gulf of Mexico which is eradicating aquatic life. This study applies the Coase Theorem and measures the economic feasibility of a WQT market in the Kentucky River watershed from the perspective of PS. Using a survey-based approach, this study will generate discussion both in the theoretical and practical fronts of WQT.

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## THE DEVELOPING NEED FOR THE REGULATION OF GEOTHERMAL CLOSED LOOP BOREHOLE INSTALLATIONS

David A. Jackson, P.G.  
Geologist Supervisor Registered  
Groundwater Section  
Kentucky Division of Water  
200 Fair Oaks Lane  
Frankfort, KY 40601  
Phone (502) 564-3410 ext 4932  
davida.jackson@ky.gov

Geothermal, (Ground source heating and cooling - GSHC) technology provides a proven method for saving energy costs for heating, cooling and hot water generation. Thousands of homes, businesses and manufacturing plants across the nation are already taking advantage of these energy-efficient conditioning systems.

Installation of ground source systems involves accessing the sub-surface by excavation or by drilling vertical bores. Because the sub-surface heat-exchange process occurs near or beneath the groundwater table, environmental and water resource regulatory issues make it important to “do the job right.” Correct design, materials specification and installation are critically important to maximize efficiency and minimize risk. There is not a one-size-fits-all for geothermal.

Currently, the Commonwealth of Kentucky does not regulate Closed Loop geothermal wells. It does however regulate Open Loop geothermal well installation under Kentucky Administrative Regulations, 401 KAR 6: 310.

A closed loop geothermal heat pump system differs significantly from an open loop system in that no fluids present in the internal processes of the system are in contact with the environment. In a closed loop system, all fluids are pumped through a “closed” circuit of piping, and the fluids never come into contact with the surrounding soil, rock, groundwater, or surface water body.

An open loop system, however, utilizes a pumping well to supply water to the heat exchanger and, most commonly, the spent water is then returned to either another well, an injection well, or to the same well, or to a surface water body.

Recently, the Kentucky Division of Water (KDOW) has responded to numerous questions, complaints and request for technical assistance relating to geothermal borehole installations. KDOW has addressed this need through onsite visits to gain firsthand knowledge of the problems related to vertical borehole installations. However, technical advice and recommendations often go unheeded in regards to KDOW’s ability to address the potential to prevent contamination of the groundwater and/or to protect homeowners from a litany of borehole construction and installation problems. This is due mainly to

the fact, that KDOW does not have legal authority to enforce construction standards or reporting requirements. Because it is our mandate to protect the Waters of the Commonwealth, KDOW moved to address these issues through the development of a “Guidance Document” to assist geothermal borehole drillers who must develop Groundwater Protection Plans (GPPs) per Kentucky Administrative Regulations 401KAR 5:037.

As the geothermal industry continues to grow, issues associated with geothermal installations are expected to grow and problems will become more prevalent. Recently, members of the Kentucky Ground Water Association (KGWA) voted overwhelmingly to support regulation of the installation of closed loop vertical boreholes. This has led KGWA with the support of Kentucky Water Well Certification Board (an advisory board to the Governor of Kentucky), and KDOW to develop requirements for addressing the need for certification and industry-wide standards. These requirements have been presented as draft legislation to amend KRS 223 in the 2012 legislative session of the General Assembly of the Commonwealth of Kentucky.

## STRATEGIES FOR EFFECTIVE MANAGEMENT AND MITIGATION OF NONPOINT SOURCE POLLUTION WITHIN WELLHEAD PROTECTION AREAS

Jessica Moore, Chad Von Gruenigen, and Jack Stickney  
200 Fair Oaks Lane  
Frankfort, KY 40601  
502-564-3410  
Jessica.moore2@ky.gov

Wellhead Protection focuses on the prevention of groundwater contamination by managing potential contaminant sources within the recharge area of a well or spring. Once delineated, this recharge area becomes the Wellhead Protection Area (WHPA) for that groundwater source. Solely identifying potential contaminant sources does not mitigate the possibility for contamination. Public Water Systems (PWS) relying on groundwater must be proactive in the development and implementation of management strategies in order to have effective Wellhead Protection Plans (WHPPs).

Potential contaminant sources include both point and nonpoint sources. Point sources are often controlled through the development and implementation of Groundwater Protection Plans (GPPs) or other permitting initiatives. GPPs are required for any activity that has the potential to contaminate groundwater, per 401 KAR 5:037. Nonpoint sources are difficult to identify and manage because they have collective effects over broad areas. Pollution from some nonpoint sources, such as agricultural runoff and onsite septic systems, can be mitigated through alternate land uses, best management practices (BMPs), and installation of municipal sewer systems within the protection area. Land acquisition by groundwater systems is especially effective because the water system can then dictate the land use within their WHPA.

Proposed management strategies for most water systems typically include a combination of public education and regulatory compliance. Regulatory compliance includes state and local regulations, as well as any local or city ordinances passed pertaining to the WHPA. Public education efforts typically include public meetings, brochures, fliers, mailings, Consumer Confidence Reports, and posted notices. Successful implementation of these strategies depends on the resources available to the system and the nature of the contaminants. In order for any management strategy to be effective the utility must have cooperation between the plant operators, the utility water board or commission, businesses and residents within the protection area.

Oldham County Water District (OCWD) is one example of a PWS that has taken a very proactive approach toward implementing their WHPP. In conjunction with the management strategies listed above, OCWD sponsored an ordinance requiring the use of modified onsite septic systems for all new construction within their WHPA. To reduce the financial impact of the ordinance on developers and home owners, the water system offers grants that can be used to offset the cost of installing the modified septic systems in new and existing residences. This ordinance also aided in preventing the construction of a

large-capacity lateral field within the WHPA. Additionally, OCWD has purchased much of the land within its own WHPA. This allows for direct control over what activities can take place, and for the exclusion of potential contaminant sources. OCWD continues to develop and implement management strategies to better protect their groundwater source from existing and future threats.



## STATUS AND EARLY FINDINGS AT THE KENTUCKY HORSE PARK MONITORING STATION

James C. Currens, M.S., James S. Dinger, Ph.D., Junfeng Zhu, Ph.D., Mike Farwell  
Kentucky Geological Survey, University of Kentucky, 859-257-5500  
currens@email.uky.edu

Royal is the largest spring in the Inner Bluegrass, from which Georgetown gets most of its drinking water. The springshed includes a large percentage of urban development in Lexington which makes water-quality monitoring an important tool for identification and mitigation of contaminate sources. The Kentucky Horse Park is a critical site in the springshed because the cave diverges from the Cane Run surface watershed in the park near the Scott county line. Swallow holes are ubiquitous along the surface channel and the middle reaches are dry most of the year. The main conduit was discovered by; 1) observing the slope of the potentiometric surface in the wells, 2) application of a conceptual model of a cave flanked by anastomotic channels and to the results from the drilling, and 3) by reaffirming an anomaly measured on an electrical resistivity profile in 2007 had special significance compared to the later ER profiles. The cave was intercepted at a depth of 18 meters as indicated by a bit drop and loss of return circulation.

Inspection of the cave with a submersible borehole video camera recorded the passage as a meter high but the camera was inadequate to illuminate distant walls. Doppler sonar has also been used to delineate the cave dimensions. The instrument is intended for open water but its' cylindrical shape and the transponder configuration made it possible to lower it into the wells. Stationary hard echoes (amplitude greater than 45, velocity less than 0.01 m/sec) are attributed to walls, fallen rock, and ceiling pendants.

The 20-meter depth and the potentiometric surface rising 6 meters above the cave ceiling made instrumentation a challenge. Well 20 has a 12-volt submersible pump and Well 25 has a Marsh-McBirney 201-D electromagnetic flow velocity meter. Well 23 against the south wall has an YSI 6920v2 water quality logger. Well 24, on the north wall, has a Telog stage recorder (as do five other wells). The pump discharges to a carboy from which water samples are collected. A timer on the pump and an ISCO auto sampler are synchronized. Water quality data are recorded on a Campbell 200s data logger. Well 24, on the north wall of the conduit, and five other wells, have standalone Telog data loggers with Druck pressure transducers. Only a few water samples have been collected to date.

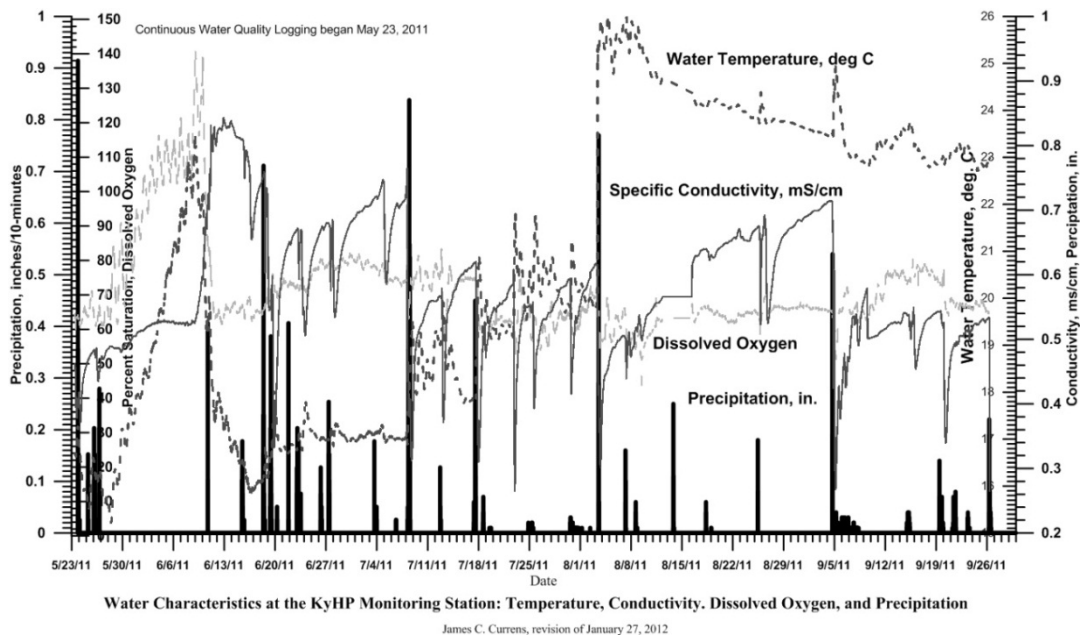
The gauge at Berea Road recorded 12 inches of rain in April 2011 and 7 inches the first three weeks of May. The last week of May and the first week of June had no rain. The water-quality logger was operational May 24, 2011. A sharp rise in water temperature, a rise in conductivity, and a peak in dissolved oxygen were recorded thru June 10<sup>th</sup> (Fig. 1). Flow velocity and water level remained nearly constant. Water temperature and conductivity returned to groundwater like values abruptly early on the 10<sup>th</sup>. An afternoon thunderstorm yielded one inch of rainfall late on the 10<sup>th</sup>. The Cane Run channel was inspected from Berea Road to the Spindletop Country Club on June 16. Inflow to swallow holes was not observed but there were isolated pools. A large pond is located on Cane Run at Spindletop. We hypothesize that water in the pond and/or the discharge from interbasin springs was sustaining the inflow into the Cane Run before the 10<sup>th</sup>. The water

in the pond or flow down the channel became warmed and oxygenated from aquatic plants. When surface water stopped flowing into the swallow holes, the groundwater temperature, conductivity, and dissolved oxygen shifted back to that of groundwater. Alternatively the rapid drop in temperature, etc. could be augmented by the cooler intense rainfall June 10<sup>th</sup>. If similar conditions occur again we will make observations at the pond and at any interbasin springs that can be found.

An interesting phenomenon is the relatively fast rate of rise of the potentiometric surface in the main conduit resulting from intense rainfall, as opposed to the water level recorded in the lateral wells. There is nearly instantaneous communication of pressure along the length of the conduit, whereas smaller conduits, bedding planes, and joints flanking the conduit have just enough resistance to flow that the volume of water that must be moved to equilibrate the pressure cannot occur fast enough to prevent a lag in the stage in the flanking wells versus those in the main conduit.

Work continues on measuring the cross-section of the conduit wider flow zone. The Doppler sonar and the down-hole video can only “see” the main conduit. The cross-section by video is 5 square meters. Constant-injection-rate groundwater traces are used to determine the total discharge along with a second tracer injected as a slug to measure velocity. A maximum cross-section of 28 m<sup>2</sup> is suggested but more traces are needed to verify the velocity and total discharge under a variety of flow conditions.

Other UK researchers are taking advantage of the facility at the Kentucky Horse Park. The site has also been a stop on three field trips during the past six months and by several individuals. We anticipate several papers from the data already on hand and more data are constantly being gathered. Guests are welcome to visit the site. Major support provided from SB-271 funds by the University of Kentucky College of Agriculture.



**Figure 1. Chemographs from the first data recorded at the Kentucky State Horse Park groundwater monitoring station, Royal Spring aquifer.**

## FLUID EVOLUTION IN CAMBRIAN-ORDOVICIAN KNOX GROUP RESERVOIRS

Thomas (Marty) Parris<sup>1</sup> and M.W. Bradley<sup>2</sup>

<sup>1</sup>Kentucky Geological Survey  
228 MMRB, Lexington, KY 40506  
859-323-0527  
mparris@uky.edu

<sup>2</sup>U.S. Geological Survey, Tennessee Water Science Center  
Suite 100 640 Grassmere Park  
Nashville, Tennessee 37211  
615-837-4703;  
mbradley@usgs.gov

Carbonate strata in the Cambrian-Ordovician Knox Group, where buried to 2,500 ft. or deeper in the Appalachian and Illinois Basins of Kentucky, are being investigated as a potential reservoir for geologic carbon sequestration. An analysis of archived formation water chemistry data (n~ 930) shows that Lower Ordovician and older reservoirs, including Knox Group reservoirs, are less saline than would be predicted by salinity trends in Silurian and younger reservoirs. The less saline water in the Knox Group suggests the possible influence of meteoric water, but it is not clear whether the meteoric water originated as “old” meteoric water that penetrated exposure surfaces during or shortly after Knox deposition or relatively “young” meteoric water that infiltrated along structural highs, such as the Cincinnati Arch. Distinguishing the causal mechanism is critical as infiltration of “young” meteoric water from the Cincinnati Arch into the deeper basin would imply that injected CO<sub>2</sub> could migrate the opposite direction driven by buoyancy forces.

The role of the Cincinnati Arch in fluid evolution in Knox Group reservoirs was investigated using bulk and isotopic (d<sup>18</sup>O-H<sub>2</sub>O, dD-H<sub>2</sub>O) chemistry measurements from three geographic areas along the Cincinnati Arch: (1) the Jessamine Dome or Bluegrass region of north-central Kentucky, (2) the south-central Kentucky and north-central Tennessee region where Knox group reservoirs often produce oil and gas, and (3) the Nashville Dome of Tennessee. Most of the water samples came from upper Knox Group carbonates including the Beekmantown Dolomite and Chepultepec Dolomite at depths of less than 100 to approximately 2,500 ft. below ground surface.

Waters in south-central Kentucky were NaCl-rich and salinity ranged from 12,400 to 108,000 mg/L, TDS. Waters from the Bluegrass and Nashville Dome areas, in contrast, were less saline (467- 8,189 mg/L, TDS) and compositionally more variable (NaCl-, NaHCO<sub>3</sub>-, and CaHCO<sub>3</sub>-rich waters). Chloride:bromide ratios for south-central Kentucky waters were similar to seawater (Cl:Br= 290), and, along with the higher salinities,

support the hypothesis that little, if any, meteoric water infiltrated the Knox in this area. Chloride:bromide ratios in the Bluegrass area are mostly lower (39 to 292), and  $\delta^{18}\text{O}$  and  $\delta\text{D}$  data for the Bluegrass ( $\delta^{18}\text{O} = -7.3$  to  $-8.1$  per mil,  $\delta\text{D} = -41$  to  $-57$  per mil) and Nashville Dome ( $\delta^{18}\text{O} = -5.9$  to  $-6.4$  per mil,  $\delta\text{D} = -34$  to  $-36$  per mil) areas fall on or close to the meteoric water line. Collectively, the data support dilution of Knox waters by meteoric water in the Bluegrass and Nashville Dome areas.

Chloride concentrations are similar between the Bluegrass (11- 1,300 mg/L) and Nashville Dome (15- 1,500 mg/L) areas, which suggests that they were similarly influenced by meteoric flushing. The similarity diverges, however, when the ratio of chlorine-36 to total chlorine is measured. Chlorine-36, produced largely in the atmosphere by cosmic ray interactions with argon-40, has a half-life of 301,000 years. Upon entering the groundwater system as precipitation, the ratio of chlorine-36 to total chlorine in meteoric water declines with time. Chlorine-36:total chlorine values for the Nashville Dome area range from 160 to 709 ( $n = 7$ ) with most ratios being slightly less than the value for meteoric water before nuclear testing (400). This suggests that dilute Knox groundwater in the Nashville Dome area is relatively young meteoric water. Bluegrass chlorine-36:total chlorine values, in contrast, are markedly lower and range from 1 to 176 ( $n = 6$ ) with five ratios being less than 6. The low chlorine-36:total chlorine values suggest that Knox waters in the Bluegrass region have attained secular equilibrium. If correct, this would suggest that, although dilute, Knox groundwater in the Bluegrass region is possibly older than 1.5 million years old.

## SIMULATING LONG-TERM FATE OF CO<sub>2</sub> FOR A WESTERN KENTUCKY DEEP SALINE RESERVOIR CO<sub>2</sub> STORAGE TEST

Junfeng Zhu, Thomas M. Parris, J. Richard Bowersox, and David C. Harris  
Kentucky Geological Survey, University of Kentucky  
504 Rose St., 228 MMRB, Lexington, KY 40506  
Tel: (859) 323-0530  
Email: Junfeng.zhu@uky.edu

Geologic sequestration is the process of injecting carbon dioxide (CO<sub>2</sub>) into deep subsurface rock formations for long-term storage, as a means to reduce CO<sub>2</sub> emissions to the atmosphere. Research is under way across the nation to determine where and to what degree this technology can be used. The Cambrian-Ordovician Knox Group, a 4000-foot-thick sequence of dolostone and minor dolomitic sandstone, is a prospective sequestration target in the southern Illinois Basin. Thorough evaluation of the Knox Group is critical because the main sequestration target elsewhere in the Illinois Basin, the Cambrian Mount Simon Sandstone, is thin or absent throughout most of western Kentucky. The Kentucky Geological Survey, as part of the Kentucky Consortium for Carbon Storage, drilled an 8,126-foot-deep test well (KGS #1 Blan well) in Hancock County, Kentucky, and injected 690 tons of CO<sub>2</sub> into the Knox Group dolostone and sandstone reservoirs.

Evaluation of well and core data indicate that the Knox Group has reservoir properties suitable for CO<sub>2</sub> storage and that the overlying Maquoketa Shale has sealing capacity sufficient for long-term confinement. Injection testing with brine and CO<sub>2</sub> was completed in two phases. The first phase tested the entire Knox in the open borehole at 3,780–7,397 feet below casing cemented at 3,660 feet, and the second phase tested a mechanically-isolated dolomitic-sandstone interval at 5,038–5,268 feet.

To understand the long-term fate of CO<sub>2</sub> injected into the Knox reservoirs, geochemical reactions among CO<sub>2</sub>, brine, and rock-forming minerals were modeled using TOUGHREACT. The model benefited from a robust data set collected from the KGS #1 Blan well, including core porosity and permeability, petrographic and XRD mineralogy, brine chemistry, and temperature and pressure measurements. Kinetic batch models and 1-D radial reactive transport models were used to evaluate the migration of the injected CO<sub>2</sub>, mineral dissolution and precipitation.

Results from these models suggest (1) mineral trapping capacity of dolomite rocks for CO<sub>2</sub> is small and the majority of CO<sub>2</sub> will remain in aqueous or supercritical/gas phases for a long time, (2) injected CO<sub>2</sub> causes dissolution of dolomite and precipitation of dawsonite and quartz, (3) presence of siliciclastic minerals, such as k-feldspar, facilitates mineral trapping, and (4) the radius of influence of the injected CO<sub>2</sub> from the tests is about 30 feet from the well.

## NOTES

[illegible]

WESTERN KENTUCKY DEEP SALINE RESERVOIR CO<sub>2</sub> STORAGE TEST:  
SHALLOW GROUNDWATER MONITORING RESULTS

E. Glynn Beck  
Kentucky Geological Survey, Western Kentucky Office  
1401 Corporate Court, Henderson, KY 42420  
270-827-3414 ext. 23  
ebeck@uky.edu

Daniel Wedding  
Kentucky Geological Survey, Western Kentucky Office

Thomas M. Parris  
Kentucky Geological Survey  
228 Mining and Mineral Resources Building, Lexington, KY 40506  
859-323-0527  
tmparr2@uky.edu

David A. Williams  
Kentucky Geological Survey, Western Kentucky Office  
270-827-3414 ext. 22  
williams@uky.edu

In 2007, the Kentucky General Assembly through House Bill 1 mandated that the Kentucky Geological Survey conduct research that "... shall include the drilling of deep wells in both coal fields (Illinois and Appalachian) in Kentucky, and performing the analysis necessary to estimate the potential for enhanced oil and gas recovery, enhanced coalbed methane recovery, or permanent storage of sequestration of carbon dioxide."

As part of this mandate, a deep test well was successfully drilled to a depth of 8,120 ft in Hancock County, Kentucky in 2009. The potential to inject and store carbon dioxide was successfully tested by injecting 323 tons of CO<sub>2</sub> on August 18, 2009 (phase I) and an additional 367 tons of CO<sub>2</sub> on September 22, 2010 (phase II). During phases I and II, CO<sub>2</sub> was injected into Knox Group saline aquifers below a depth of 3,570 ft. The deep test well was plugged and abandoned on October 18, 2011. Additional information about the drilling and testing of the deep test well can be reviewed by visiting the Kentucky Consortium for Carbon Storage Web site at [www.uky.edu/KGS/kyccs](http://www.uky.edu/KGS/kyccs).

In an effort to locate existing, shallow groundwater sites to monitor any potential groundwater changes associated with CO<sub>2</sub> injection, survey letters were sent to all identified owners of land parcels within the 2-mi area of review of the deep test well. Two domestic wells and two domestic springs were identified. One domestic well (MB1) is located on the same property as the deep test well. Groundwater-baseline sampling began at this site in December 2008. One domestic spring (RC1) is located just outside of the 2-mi area of review. Sampling at spring RC1 and the other two identified sites (well

GB1 and spring CA1) began in April 2009 in conjunction with the issued underground injection control permit.

The underground injection control permit states, “The permittee (KGS) will conduct an analysis on the two existing water wells and two springs within the Area of Review. Baseline samples shall be taken prior to injection. The water wells and springs shall be monitored quarterly for pH, bicarbonate ( $\text{HCO}_3$ ), total dissolved solids (TDS), and turbidity. The sampling should begin on the effective date of this permit and every three months (quarterly) thereafter until permit expiration.” Each site was sampled at least five times prior to phase I  $\text{CO}_2$  injection. In addition to monitoring the four geochemical parameters required by the underground injection control permit, field measurements (specific conductance, dissolved oxygen, and temperature), metals, anions, dissolved inorganic carbon (DIC), total  $\text{CO}_2$  ( $\text{TCO}_2$ ), and  $\delta^{13}\text{C}$  of dissolved inorganic carbon were monitored. After phase I  $\text{CO}_2$  injection, each site was sampled quarterly for field measurements, pH, turbidity, TDS,  $\text{HCO}_3$ , and  $\text{TCO}_2$ . In addition to these parameters, during the fourth quarter, each site was sampled for metals, anions, DIC, and  $\delta^{13}\text{C}$  of dissolved inorganic carbon. A similar sampling procedure was implemented following the completion of phase II injection.

Bicarbonate, TDS, pH, and turbidity data for well GB1 and springs RC1 and CA1 increased and decreased slightly over time, but post-injection values deviated very little from pre-injection values. Bicarbonate and TDS concentrations for well MB1 increased after each  $\text{CO}_2$  injection, but began to increase approximately one month prior to each injection and were most likely related to increased groundwater recharge associated with increased precipitation. In addition to these data,  $\delta^{13}\text{C}$  values of the  $\text{CO}_2$  injectate, local soil gas, and shallow groundwater indicate that injected  $\text{CO}_2$  has not altered the local groundwater quality within the 2-mi area of review of the deep test well. Sampling of wells MB1 and GB1 and springs RC1 and CA1 is currently scheduled to continue through October 2013.



## BASELINE SOIL PROPERTIES OF A CENTRAL KENTUCKY RIPARIAN BUFFER

Amanda A. Gumbert  
N-122C Ag Science North, Lexington, KY 40546-0091  
859-257-6094  
Amanda.Gumbert@uky.edu

Mark S. Coyne  
N-122N Ag Science North, Lexington, KY 40546-0091  
859-257-4202  
Mark.Coyne@uky.edu

Ole O. Wendroth  
N-122M Ag Science North, Lexington, KY 40546-0091  
859-257-4768  
owendroth@uky.edu

The Kentucky Division of Water labels agriculture as the leading source of stream impairments in the state, with 55% of streams not supporting their designated uses due to agriculture. Riparian buffers reduce nonpoint source pollution in agroecosystems by storing and cycling nutrients, stabilizing stream banks, increasing infiltration, and storing water. Specific information on riparian buffer maintenance is needed for agricultural producers to maximize the potential benefits to water quality through the utilization of riparian buffers. Understanding existing buffer soil properties and spatial variability will enhance management strategies to maximize riparian buffer function. Parallel transects were established at 2-m and 8-m distances from top-of-bank along a 650-m straightened agricultural stream section. In July 2010, soil samples were collected at 10-m intervals along transects, divided into 10-cm depth increments, and analyzed for soil texture, pH, nutrient content (P, K, Ca, Mg, and Zn), total C, and total N content. Soils along the 2m transect differed significantly from the soils along the 8m transect. The 2m transect soils had greater C content, higher pH, higher Ca and Zn, lower P, K, and Mg, greater sand content, and lower clay content than soils along the 8m transect location. Initial semivariogram analysis of C content indicates spatial structure along the 2m transect at 50m and along the 8m transect at 100m. This result suggests that buffer soil properties closer to the water body may be more variable than those further from the stream, requiring more careful management to maximize buffer efficacy.

## NOTES

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## THE KENTUCKY WATER WELL DRILLER'S CERTIFICATION PROGRAM

Scotty E. Robertson, P.G., and David A. Jackson, P.G.  
Kentucky Division of Water  
200 Fair Oaks Lane  
Frankfort, KY 40601  
Phone (502) 564-3410 ext 4943  
scotty.robertson@ky.gov  
davida.jackson@ky.gov

The primary purposes of the Kentucky Water Well Driller's Certification Program are to certify water and monitoring well drillers and to enforce well construction practices and standards. The program administers driller license, certification exams, provides driller training, attends the Kentucky Water Well Board meetings, manages the driller's database, oversees bonding and insurance requirements, inspects wells for compliance, and investigates citizen complaints.

The program began in 1985 under the authority of KRS 223.400. Initially, certification was only required for water well drillers. However, monitoring well drillers were added in 1992. Currently, 120 drillers are certified: 55 to drill monitoring wells only; 36 certified to drill both water and monitoring wells; and 29 certified for water wells only.

As public water lines have extended into rural areas, the number of water wells drilled has generally declined. For example, the highest number of water wells reported since the certification program was implemented was 2,774 in 1988, compared to less than 500 in 2011. The number of monitoring wells reported annually has also decreased during the last few years partly due to the slow economy.

The program provides numerous publications for well drillers and owners, including the Kentucky Driller Quarterly Newsletter, the Directory of Certified Water and Monitoring Well Drillers, Routine Water Well Maintenance and Disinfection Guide, Protecting Your Well and Water Supply, and Methane Gas and Your Water Well. These publications are available on the Division of Water web site at:

<http://water.ky.gov/groundwater/Pages/WellDrillersProgram.aspx>

The program enforces well construction standards and provides technical assistance to drillers, consultants, and the public. Drillers are required to submit well logs for each well they drill, and agency personnel also submit well and spring inspection reports. Over 62,000 wells and springs have been entered in the Groundwater database. Information on these sites includes depth to groundwater, location, construction details, and groundwater quality and quantity. Investigation of citizen complaints is an important part of the program, and often involves water quality sampling and downhole camera inspections.

## NOTES

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INFLUENCES OF A *CLADOPHORA* BLOOM ON THE DIETS OF *AMBLEMA*  
*PLICATA* AND *ELLIPTIO DILATATA* IN THE UPPER GREEN RIVER, KENTUCKY

Jennifer M. Yates, Scott A. Grubbs, and Albert J. Meier  
Department of Biology, Western Kentucky University, Bowling Green, Kentucky 42101  
(270)745 3696  
jennifer.yates101@topper.wku.edu

Freshwater mussels cycle nutrients, link multiple trophic levels, and stimulate primary production. Mussels are typically classified in riverine systems, feeding on a combination of sestonic algae, bacteria, and detritus. Filamentous algal fragments have been found in digestive tracts, however, suggesting they may alternatively graze when macroalga are available as a food source. This study addressed two questions: (1) does growth of two species of mussels, *Amblema plicata* and *Elliptio dilatata*, differ in stream reaches with markedly different *Cladophora* cover, and (2) are their diets reflective of the availability of *Cladophora* during periods of rapid summer growth? The study took place in June – November 2011 in a 7<sup>th</sup> –order reach of the upper Green River located at the Western Kentucky University Upper Biological Preserve in Hart County, Kentucky.

Seventy-two mussels were collected from shoal habitats. One of each species was placed into thirty experimental growth silos and returned to shoals in randomly assigned transects. The remaining 12 mussels, six per species, were used for initial growth and stable isotopic ratio data. Biomass levels of sestonic and filamentous algae were quantified monthly, including following the first major scouring event that removed most of the *Cladophora* from the study reach in early September. Mussels were sampled across four timepoints from areas of both very high (i.e., natural, *in-situ* levels) and very low (i.e., repeated removal) regions of *Cladophora* growth. Mussel growth was tracked by quantifying changes in shell length and total weight wet. Diet was assessed by comparing natural carbon ( $^{13}\text{C}/^{12}\text{C}$  or  $\delta^{13}\text{C}$ ) and nitrogen ( $^{15}\text{N}/^{14}\text{N}$  or  $\delta^{15}\text{N}$ ) isotopic ratios of several potential food resources and body tissues of both mussel species. Food resources included *Cladophora*, the vascular riverine macrophyte *Podostemum ceratophyllum*, riparian tree leaves, epilithic biofilm, transported organic matter (TOM) and colloidal dissolved organic matter. The TOM component was separated into two separate size fractions, 1000-100  $\mu\text{m}$  and 100-1 $\mu\text{m}$ . Biofilm and both TOM components were partitioned, using a silica-based centrifugation technique, into separate algal and detrital fractions.

Analysis of covariance (ANCOVA) showed that the presence of *Cladophora* was not a significant predictor of overall growth for either mussel species. The  $\delta^{13}\text{C}$  values ranged considerably from the macrophyte *P. ceratophyllum* (mean:  $\delta^{13}\text{C} = -37.7 \pm 0.2$ ) to the 100–1 $\mu\text{m}$  TOM fraction ( $\delta^{13}\text{C} = -28.3$ ) (Table 1). The algal and detrital  $\delta^{13}\text{C}$  values were nearly identical for the 1000–100  $\mu\text{m}$  fraction (-28.9 vs. -28.8) and also similar for the 100–1 $\mu\text{m}$  (-28.3 vs. -27.9) components. In contrast, the two epilithic biofilm components

had markedly different  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  signatures. Mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for both mussel species were similar, but also shifted between July and August (Table 1). Mean  $\delta^{13}\text{C}$  values for *A. plicata* shifted from -32.5 to -33.6 compared to a -32.6 to -33.7 shift for *E. dilatata*. During July the  $\delta^{13}\text{C}$  signature for both mussel species was most closely aligned with that of epilithic biofilm. The temporal shift, however, between July and August suggested mussels were assimilating increasingly more *Cladophora* tissue during the rapid summer growth period.

**Table 1. Mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N} \pm 1$  S.E. values for consumers and food resources**

Sample	n	Mean $\delta^{13}\text{C} \pm \text{S.E.}$	Mean $\delta^{15}\text{N} \pm \text{S.E.}$
Resources			
<i>Podostemum ceratophyllum</i>	5	-37.74 $\pm$ 0.21	8.11 $\pm$ 0.17
<i>Cladophora</i>	5	-34.20 $\pm$ 0.66	3.89 $\pm$ 0.11
terrestrial leaf litter	5	-30.87 $\pm$ 0.12	4.28 $\pm$ 0.10
detrital epilithic biofilm	1	-31.85	7.74
algal epilithic biofilm	1	-28.39	6.09
detrital TOM 1000–100 $\mu\text{m}$	1	-28.80	*14.36
algal TOM 1000–100 $\mu\text{m}$	1	-28.90	*14.36
detrital TOM 100–1 $\mu\text{m}$	1	-27.87	4.60
algal TOM 100–1 $\mu\text{m}$	1	-28.34	4.49
Consumers			
<i>Amblyma plicata</i> (Jul)	6	-32.51 $\pm$ 0.07	8.76 $\pm$ 0.09
<i>Amblyma plicata</i> (Aug)	6	-33.56 $\pm$ 0.09	8.62 $\pm$ 0.12
<i>Elliptio dilatata</i> (Jul)	6	-32.55 $\pm$ 0.09	8.48 $\pm$ 0.08
<i>Elliptio dilatata</i> (Aug)	6	-33.67 $\pm$ 0.06	8.42 $\pm$ 0.07

\*Sample size <10 ug N, therefore data must be interpreted with caution.

These findings provide evidence that both mussel species were assimilating benthic food resources, particularly epilithic detritus and perhaps *Cladophora*, during summer. There is little evidence that either species was feeding on either the algal or detrital component of TOM. Stable isotope data for all resources and both consumer species is upcoming for September and October.

USING ELECTRICAL RESISTIVITY TO LOCATE  
AN ABANDONED FLUORSPAR MINE AS A SUPPLEMENTAL WATER SOURCE  
FOR THE CITY OF MARION, KENTUCKY

E. Glynn Beck  
Kentucky Geological Survey, Western Kentucky Office, 1401 Corporate Court  
Henderson, KY 42420  
270-827-3414 ext. 23  
ebeck@uky.edu

Scott Waninger, Ron Counts, Daniel Wedding  
Kentucky Geological Survey, Western Kentucky Office, 1401 Corporate Court  
Henderson, KY 42420

John Tapp  
Florence & Hutchenson, Inc.  
2550 Irvin Cobb Drive  
Paducah, KY 42003  
270-444-9691  
jtapp@flohut.com

Junfeng Zhu  
Kentucky Geological Survey  
228 Mining and Mineral Resources Building  
Lexington, KY 40506

The primary drinking-water source for the city of Marion, KY, is a 42-acre reservoir known as Lake George. Lake George has a drainage area of approximately 750 acres and has an average depth, at the intake structure, of 30 ft. In 2007, extreme drought conditions resulted in a drawdown in the water level of 8 to 10 ft below the average depth, which was close to falling below the depth of the intake. Because of this drought-induced drawdown, the city of Marion began looking for alternate sources of raw water to supplement Lake George during future dry seasons.

The Lucille fluorspar mine, which was abandoned in the 1930's and is located on city property, provided an ideal potential alternate source of raw water. A detailed plan-view and cross-section map of the mine shows the depth of old workings (40–230 ft), shaft locations, and the location of a dewatering well, which was completed in an abandoned mine shaft. Surface features shown on the old mine map, which might be used to correctly orient the mine (shafts, water well, etc.) on recent aerial imagery, have long been removed. Consequently, the map could not be used to link old workings and shafts to surface features, so the location of the mine in the subsurface could not be determined. City officials asked researchers from the Kentucky Geological Survey to conduct an electrical-resistivity survey over the mine site to attempt to locate subsurface mine

features (shafts and workings), which could be used as reference points to orient the mine map and serve as potential drilling targets to install test wells into the mine.

In 2010, eight electrical-resistivity profiles were measured on the property overlying the abandoned Lucille Mine. Seven parallel profiles transected the property from northwest to southeast and were spaced 50 ft apart. These profiles were approximately 400 ft long. The eighth profile was approximately 690 ft long and transected the property in a southwest-northeast direction, cutting across the first seven profiles. The electrode spacing for all profiles was 10 ft, and the two dimensional, direct-current resistivity data were collected using a dipole-dipole array. Although not conclusive without drilling confirmation, inversion results of all eight profiles show conductive anomalies, which may correlate with water-filled mine workings.

In 2011, in an effort to locate buried mine features, city of Marion Public Works personnel used backhoes to open shallow excavations at several locations on the abandoned mine property, and two buried water wells were located. Each well was videoed and gamma-ray logged by Kentucky Geological Survey personnel. Video and gamma-ray log results indicate that one of the wells is completed in an abandoned mine shaft. This well is believed to be the dewatering well on the mine map. The other well is believed to be the water-supply well previously used by Marion. Using the identified shaft location, the mine map can now be correctly oriented and can be used in conjunction with the electrical-resistivity data to propose a more cost-efficient and effective drilling program.

Also in 2011, preliminary water-quality samples were collected from the old dewatering well completed in the mine shaft. Groundwater sampled from the well had a fluoride concentration of 3.5 mg/L, which is above the secondary maximum contaminant level of 2.0 mg/L. The city of Marion plans to have the dewatering well pumped to determine potential drawdown in the mine and to collect additional water samples during pumping to see if the quality of the mine water changes over time.



## NUTRIENT AND FECAL MICROBE ASSESSMENT OF THE WATER QUALITY OF TATES CREEK, MADISON COUNTY, KENTUCKY

Walter S. Borowski and Kristopher Carroll  
Dept. Geography and Geology  
Eastern Kentucky University  
Richmond, KY 40475  
(859) 622-1277  
w.borowski@eku.edu

Tates Creek is a significant tributary to the Kentucky River that has shown high levels of microbial and nutrient pollution in the past (Kentucky River Watershed Watch). We sampled the waters of Tates Creek more comprehensively by collecting stream water at 25 stations along its 13-mile length from its headwaters to the Kentucky River. Most samples were collected at the confluence of major tributaries to also assess the water quality of tributary streams. Samples were collected four times between May and August 2011 during dry periods as well as immediately after a rainfall event. We measured ammonium ( $\text{NH}_4^+$ ), nitrate ( $\text{NO}_3^-$ ), and phosphate ( $\text{PO}_4^{3-}$ ) concentrations using colorimetry. Microbial samples were measured for total coliform and *Escherichia coli* using IDEXX Colilert-18 media and methods.

Background levels of  $\text{NH}_4^+$ ,  $\text{NO}_3^-$  and  $\text{PO}_4^-$  are typically ~0.3 mg/L, 5 mg/L, and 1.0 mg/L, respectively. Thus, phosphate concentration almost always exceeds EPA criteria for freshwater (0.1 mg/L). Background levels of nutrient concentrations generally increase during rainfall events, presumably because nutrients are flushed into the stream. Background counts of *E. coli* are typically ~100 cfu/mL but *E. coli* counts reached 1,000 to 2,419 cfu/mL immediately following rain events. Some areas also show microbial counts far in excess of background levels. Microbe counts tend to be high in the headwaters of Tates Creek where we suspect leaky and/or broken sewage lines are responsible for high *E. coli* counts. Other high counts also occur adjacent to active pasture. Thus, fecal microbe pollution in Tates Creek occurs from both human and bovine sources.

A sewage treatment plant existed approximately two miles from the headwaters of Tates Creek and noticeably affected water quality. Upstream of the plant, nutrient levels are low, whereas nutrient concentration, especially  $\text{NH}_4^+$  and  $\text{PO}_4^-$ , were markedly increased at the plant's outflow. These nutrients then decreased steadily in concentration downstream to background levels. In contrast, when the plant was operating fecal microbe counts were high upstream from the plant, but fell to near-zero levels at its outflow, and then increased anew downstream. The treatment plant went off line on 19 July 2011 and subsequent sampling showed nutrient levels no longer spike immediately downstream. *E. coli* counts remained high upstream and downstream of the plant because stream waters are no longer diluted by plant outflow that carried almost no microbes. A companion study sampled stream biota before and after the plant shut down. Thus, we will be able to note any changes in stream biota attributable to changing nutrient levels.

## NOTES

[illegible]

# DETERMINING THE EFFECTIVENESS OF CONDUCTIVITY AS A STREAM QUALITY INDICATOR IN SOUTHERN APPALACHIA USING GIS

Elliott Baldrige<sup>1\*</sup>, Dr. Alice Jones<sup>1</sup> Dr. James F. Fox<sup>2</sup>

<sup>1</sup>Eastern Kentucky University  
Eastern Kentucky Environmental Research Institute  
3106 New Science Building Richmond, KY 40476  
859.622.6914  
elliott\_baldrige@eku.edu

<sup>2</sup>University of Kentucky  
Department of Civil Engineering  
354G Raymond Building  
Lexington, KY 40506

The objective of this study was to compare several methods of stream quality analysis; dissolved oxygen, pH, temperature, rapid habitat assessment, macroinvertebrate health data, salamander data, metals analysis, and conductivity to determine whether or not the conductivity readings agreed with the results of the other stream quality analysis methods. The data used in this study were collected by various individuals and the parameters determining the “good” and “bad” cutoff ranges were based on literature review and were selected by the researchers who collected the data. The study sites were all first order headwater streams within the Line Fork watershed in Letcher County, Kentucky, with varying land-use histories; pre-SMCRA (Surface Mining Control and Reclamation Act of 1977), post-SMCRA, and undisturbed old growth forest. The datasets were incorporated into ArcGIS and the technique known as geographic overlay analysis was employed to visually compare the various parameters with conductivity. The results of this study did not match the expected outcome. No correlation between conductivity and the other measures of stream quality was found. Minor correlations were observed; however, no definite relationships were determined.

## NOTES

[illegible]

## SUSPENDED SEDIMENT CONCENTRATION IN BRUSHY CREEK WATERSHED, KENTUCKY

Tyler Wade\* and Walter S. Boworski  
Eastern Kentucky Environmental Research Institute  
Eastern Kentucky University  
3106 New Science Building  
Richmond, KY 40476  
859.622.6914  
Tyler\_Wade4@eku.edu

Suspended sediment concentration (SSC) can be used as a proxy for environmental health of stream water. For example, large sediment loads can cause harm to aquatic life and are a mechanism for introducing and transporting fecal microbes. We measured SSC of the Brushy Creek watershed, located in Rockcastle, Pulaski, and Lincoln Counties, where the Eastern Kentucky University Eastern Kentucky Environmental Research Institute (EK-ERI) has been conducting an assessment of the watershed. Two auto sampling units were placed in Brushy Creek to collect water samples for determination of SSC. The units collect samples every 14 hours for a two-week period, then samples are retrieved for analysis, and new sample bottles are loaded into the auto samplers. Sediment sampling was conducted between January 2011 and November 2011. We measured sediment transport during dry, wet, and storm periods. Retrieved samples were brought to the laboratory where sediments were filtered and weighed to determine SSC. The SSC data have been evaluated along with records of rainfall events, as recorded by the UK Agriculture weather station located in Somerset. The results are somewhat intermittent because of difficulties encountered in locating and operating the sampling units, and because of the extremely flashy nature of the stream system.

Significant rainfall events caused increased flow in Brushy Creek and increased sediment transport, which was reflected in SSC. We see evidence of increased suspended sediment concentration on days that had rain events, but there are also days that have significant rainfall but little sediment activity. On these days of rainfall but little suspended sediment can be attributed to the 30 mile distance between Somerset, where the rainfall data is collected, and the location of the watershed. Since rainfall does not occur uniformly, rain may occur at the monitoring station at Somerset but little or no rain may fall in the watershed.

## NOTES

[illegible]

## RETAIL DRINKING WATER SHELF SPACE AS A MEASURE OF SURFACE WATER QUALITY IN SOUTHERN APPALACHIA

Marlana NaShae Prater\*

<sup>1</sup>Dr. Alice Jones, Faculty Advisor

Eastern Kentucky Environmental Research Institute

Eastern Kentucky University

3106 New Science Building Richmond, KY 40476

859.622.6914

shae.prater@eku.edu

Seven Kentucky counties were considered in this exploratory study to establish whether floor space devoted to bottled water in a franchised retail grocery location is a reliable secondary measure of environmental water quality. Two counties were located in central Kentucky, while five counties were located in the southeastern Appalachia region, also known as “coal country”. In order to help control for varying population sizes and consumer buying habits, floor space also devoted to soft drinks, aseptically packaged juices, milk, and bread were observed and floor space was assessed as a ratio of total square feet devoted to grocery items at each individual store. Bread was used as a staple product control for liquid items, which may be bought as a replacement for drinking water in the home.

Environmental surface water specific conductivity was obtained from three water quality databases (the Eastern Kentucky Environmental Research Institute, the Kentucky Geological Survey/Division of Water, and the Kentucky Watershed Watch). The greatest challenge was to identify best methods for geographically grouping and relating water quality data samples to the grocery store data. A geographic information system (GIS) was used to spatially group these data using five different strategies: a buffer of individual grocery stores, a buffer of roads within grocery store buffer, watersheds, area development districts, and counties.

As expected, not all strategies were successful. Relationships between grocery commodities and average were found at the watershed, area development district, and county levels. The most promising relationships were found on the county level between conductivity and all five commodities observed. The results suggest that retail shelf space devoted to bottled water could be a reliable measure of surface water quality in coal country. There is also a relationship between surface water quality and per capita income, as well as a relationship between per capita income and retail floor space devoted to basic grocery commodities. These results suggest that where per capita income is lower, more individuals buy staple grocery commodities. Also, where per capita income is lower, surface water quality is poorer. Because the grocery store sample was small, further research is required in order to resolve issues with statistical reliability.

## NOTES

[illegible]



## MAPPING WATER QUALITY IN COAL COUNTRY: THE GIS WATERSHED DELINEATION PROJECT

Cory Hunter Cecil\* and Dr. Alice Jones  
Eastern Kentucky Environmental Research Institute  
Eastern Kentucky University  
3106 New Science Building Richmond, KY 40476  
859.622.6914  
cory\_cecil14@eku.edu

Since 2006, the Eastern Kentucky Environmental Research Institute has conducted a widespread water sampling project throughout the three major watersheds that drain Kentucky's Appalachian coalfields: The Kentucky, the Big Sandy, and the Upper Cumberland. Together these watersheds form the "Big Dip."

Over the course of four summers, more than 60 trained students and volunteers tested 1,648 water sites for varying water quality parameters as well as geo-referencing each water sample site. In summer 2010, a GIS analysis was initiated. Using the Arc Hydro program within ArcMap, the land area related to each individual water sample point was mapped. These delineations show the area of land that water from a specific point runs off and drains into. The result was a detailed map identifying each sampling point and the land area upstream that it drains—including any sites that are "nested" or within the drainage area of another site. Using the National Land Cover Dataset, the land cover type for each individual watershed was established. Next, using statistical analysis within ArcMap, the percentage of each land use within each individual watershed was calculated. By doing so, a solid connection was established between the water quality from each sample site, the watershed area that contributed to the water quality effect, and the scope of anthropogenic involvement within the watershed. Particular land uses of interest included those identified as "barren land" since these are typically associated with heavy mining activity, and represent either reclaimed mines, mountaintop removal sites, or longwall mine sites.

## NOTES

[illegible]

# WATER QUALITY IN EASTERN KENTUCKY: THE RELATIONSHIP BETWEEN WATER QUALITY AND POVERTY AT THE CENSUS TRACT LEVEL

Allison N. Woehler<sup>1</sup>, Dr. Alice Jones<sup>2</sup>, Faculty Advisor

<sup>1</sup>Humana Reconnaissance Specialist  
101 East Main Street, Louisville, KY 40202  
888-778-4651  
awoehler@humana.com

<sup>2</sup>Eastern Kentucky University  
Eastern Kentucky Environmental Research Institute  
3106 New Science Building Richmond, KY 40476  
859-622-6914  
alice.jones@eku.edu

The goal of this study was to determine if there is a positive correlation between Eastern Kentucky's poor water quality and its rampant high poverty rate. Between 2006 and 2009, more than 1600 first- and second- order streams throughout Appalachian Kentucky were sampled for baseline diagnostic water quality measures, including dissolved oxygen, pH, conductivity, temperature, turbidity, and iron levels. These data were compared with census tract level socioeconomic data to examine whether there is a relationship between poor water and poor people. In general, the results indicate that there is little relationship between water quality indicators and sociodemographics such as urban vs. rural; income and education rates, or unemployment and poverty rates. The lack of a relationship between water quality and socioeconomic characteristics may be because poor water quality is so pervasive that it affects everyone in the region, regardless of status. The other explanation may be that, on the whole, the region is relatively socioeconomically homogenous. The typical patterns of clustered or stratified income from neighborhood to neighborhood do not hold true throughout much of Appalachian Kentucky. Differences in household income and poverty rates do not vary greatly from census tract to census tract, so there are very few "wealthy" areas in the region.

## NOTES

[illegible]

LABORATORY CALIBRATION OF EXPERIMENTAL VELOCITY AND  
SEDIMENT CONCENTRATION SENSORS TO MONITOR WATER AND THE  
ENVIRONMENT

Robert Stewart  
Graduate Assistant  
Department of Civil Engineering  
University of Kentucky  
220 O. H. Raymond Bldg.  
Lexington, KY 40506-0281  
Phone: (423) 914-0460  
Email: rlst223@uky.edu

Cindy Harnett  
Assistant Professor  
Dept of Electrical and Computer  
Engineering  
University of Louisville  
248 Shumaker Research Building  
Louisville, KY 40208  
Phone: (502) 852-0689  
Email: cindy.harnett@louisville.edu

Jimmy Fox  
Assistant Professor  
Department of Civil Engineering  
University of Kentucky  
161 O. H. Raymond Bldg.  
Lexington, KY 40506-0281  
Phone: (859) 257-8668  
Email: jffox@engr.uky.edu

Thomas Lawrence  
Undergraduate Assistant  
Department of Civil Engineering  
University of Kentucky  
220 O. H. Raymond Bldg.  
Lexington, KY 40506-0281  
Phone: (859) 494-9464  
Email: twlawr2@uky.edu

The focus of this research is (i) the creation and verification of inexpensive instrumentation for sediment transport measurements within intelligent sensor networks, and (ii) the design of wireless intelligent features for minimizing cost and energy while maximizing sensor reliability and accuracy of sediment transport measurements. Recent advancement in sensor network technology promotes inexpensive, small size, and low power requirement sensors due to their faster installation, ability to safely monitor during hazardous conditions, and capability of capturing processes at scales relevant to a wide range of research. The newly developed velocity sensors are called velocity bend sensors (VBS) due to their operating mechanism. Water velocity causes the sensor, which acts as a strain gage, to bend and change the electrical resistance of the sensor. The light attenuation sediment sensors (LASS) use a cadmium sulfide light dependent resistor to measure light intensity. The light intensity in water follows the Beer-Lambert distribution in which light intensity is related to the depth of water and sediment concentration and is impacted by other constituents within the water column. Velocity bend sensors, light attenuation sediment sensors, and inexpensive pressure sensors are constructed followed by calibration and verification of the sensors in an experimental hydraulics laboratory. *Salamander* is the Serial Amphibious Linear Arrays of Micro And Nano Devices for Environmental Research, and the tool provides a versatile, instrumentation platform for deploying hydraulics and water quality sensors within stream networks. *Salamander* outfitted for estimating sediment flux at cross-sections in a

stream will be equipped with the velocity bend sensors, light attenuation sediment sensors and inexpensive pressure transducers. Within the field-deployed Salamander unit, algorithms are used to approximate velocity and sediment distribution and thereafter compute sediment flux for a stream location. Wireless intelligent features are currently being designed and implemented for use of *Salamander* within the stream network of a watershed. The sensor topology should agree with the functioning of the physical stream network, and we make use of this concept by using sensor connectivity to minimize cost and maximize data quality. To reduce costs, algorithms will interpret data collected to activate or deactivate sensors based on data gradients and thresholds. For quality assurance, an algorithm will interpret data between related sensors and nodes and deactivate or flag as possibly erroneous data. So far, results of this new technology include the design of wireless communication capabilities and circuitry for the velocity and TSS sensors along with relationships between sensor output and measured parameters. Full implementation of the project is ongoing at this time and includes collaboration between Civil Engineers at UK and Electrical Engineers at U of L. The velocity bend sensor and light attenuation sediment sensor are expected to provide measurements at temporal and spatial scales in order that parameter fluxes operating at the process-scale can be integrated within the larger scale monitoring network. Data provided by the sensors of suspended sediment load derived from the watershed can be used to calibrate hydrologic and suspended sediment transport models. The sediment monitoring network will be set up at a location where sediment fingerprinting is occurring which will provide insight into the source of the sediment. By the end of the research period, new techniques will have been developed so that instrumentation can be quickly set up in any watershed to capture in real time the hydrologic and sediment fluxes.

## DELINEATION OF SOLUTE INPUTS TO THE HEADWATERS PORTION OF THE CANE RUN/ROYAL SPRING BASIN OF NORTH-CENTRAL KENTUCKY

Catherine F. Skees and Alan E. Fryar

Department of Earth and Environmental Sciences, University of Kentucky  
101 Slone Research Building, Lexington, KY, 40506-0053  
(502) 387-3265  
cskee2@uky.edu

The Cane Run watershed, located within Fayette and Scott Counties in north-central Kentucky, is underlain by a karst aquifer that discharges to Royal Spring, which is the primary source of water for the city of Georgetown. Karst aquifers are more susceptible to contamination than conventional porous or fractured-rock aquifers because of focused recharge with minimal filtration. Water quality of karst springs can exhibit short-lived degradation following storm events. Heightened levels of contamination may compromise both aquatic life and public water supplies. Water quality of the Cane Run/Royal Spring basin is thought to have been compromised by pollution from agricultural, industrial, and residential sources. Non-point-source pollution has resulted in excess nutrients and bacteria throughout the watershed. Consequently, Cane Run has been listed by the Kentucky Division of Water as a priority stream for cleanup.

This study was initiated in late summer 2012 with the purpose of delineating solute inputs into the headwaters of the basin in north Lexington over a one-year period. Field parameters (temperature, specific conductance, pH, and dissolved oxygen), selected ions (chloride, sulfate, nitrate, and ammonium), and stable isotopes of water (deuterium and oxygen-18) have been monitored biweekly at seven sites within the basin. Chloride and stable isotopes of hydrogen and oxygen are conservative (i.e., unaffected by chemical reactions at ambient temperatures) but are affected by evaporation. Those parameters are thus useful for examining mixing of waters from different sources. Nitrate and ammonium are nutrients that can originate from agricultural sources (e.g., fertilizer and animal waste) or from leakage of sanitary sewers. Temperature, specific conductance, and pH have been measured in the field using a multi-parameter probe. Dissolved oxygen is being measured using the Winkler titration method. Ions are being analyzed via ion chromatography (sulfate and chloride in the UK Environmental Resources and Training Laboratory; ammonium and nitrate in the UK Department of Forestry). Oxygen-18 and deuterium will be analyzed in the UK Department of Earth and Environmental Sciences using a gas-source, continuous flow, isotope-ratio mass spectrometer. These same parameters will be monitored at regular intervals at two sites during two storm events, tentatively in March and June, using ISCO automated samplers.

We will use graphical and statistical analyses to examine spatial and temporal (both seasonal and event-scale) trends in water-quality parameters. Graphical techniques will include bivariate plots. Principal component and hierarchical cluster analyses will be performed using MATLAB software. Spatial variations in water-quality parameters will be displayed within a comprehensive geodatabase of the basin using ArcGIS.

## NOTES

[illegible]



## IMPACT OF NITROGEN FERTILIZATION ON SOIL MICROBIAL RESPIRATION AND PHENOL OXIDASE ACTIVITY

M. E. Barnes\*, C. J. Matocha, J. H. Grove, and M. S. Coyne  
Plant and Soil Science Department, University of Kentucky  
Phone Number: \*859-257-3515  
Email Address: \*mebarn4@uky.edu

Anthropogenic nitrogen inputs are known to alter extracellular enzymes which in turn mediate transformation reactions of soil organic matter. Past studies have noted that inorganic N fertilization negatively impacts soil phenol oxidase activity in relatively undisturbed (no-tillage) agroecosystems and forest systems. These responses have been correlated with soil organic matter concentration and dissolved organic carbon export. It is unclear whether decomposition rates of soil organic matter, as measured by respiration, are affected by N inputs in no-tillage systems. This study was undertaken to measure microbial respiration and phenol oxidase activity in no-till soil (Maury silt loam) under the influence of increasing N fertilization rates (0, 168 and 336 kg N ha<sup>-1</sup> as NH<sub>4</sub> NO<sub>3</sub>). Phenol oxidase activity values decreased 1.4- and 1.6-fold with the addition of 168 and 336 kg N ha<sup>-1</sup> when compared with the control. Reductions in phenol oxidase activity with N input were magnified when data were expressed on a soil organic carbon basis. Respiration rates based on carbon dioxide release were reduced with N inputs and were negatively correlated with available (water-extractable) nitrate. Although the exact mechanism explaining the suppression in soil respiration rate with N input is not known, the results suggest that soil organic carbon is less prone to decomposition with N additions in no-tillage agroecosystems. Future work will address the possibility of mineral stabilization of soil organic carbon and the impact of N on other extracellular enzymes.

## NOTES

[illegible]

## BY-PROXY MONITORING OF AQUEOUS NITRATE PHOTOLYSIS AND THE EFFECT OF HYDROXYL RADICAL

Jonathan O. Wyatt and Matthew J. Nee

Department of Chemistry, Western Kentucky University, Bowling Green, KY, 42101

Phone: (270) 745-0114

jonathan.wyatt560@topper.wku.edu; matthew.nee@wku.edu

A model by which we may grasp the full extent of Earth's atmospheric conditions is far from complete. There is an immense expanse where air and water meet, such as that of the oceans, rivers, lakes, and snow packs; these unaccounted sources significantly contribute to the atmospheric chemistry of our Earth and must be accounted for if we are to accurately model atmospheric conditions. The purpose of our research is to advance our understanding of the production of toxic  $\text{NO}_x$  ( $= \text{NO} + \text{NO}_2$ ) and ozone ( $\text{O}_3$ ) at the surface of water reservoirs, a mechanism that is poorly characterized. A significant input may come from reactions of nitrate ion ( $\text{NO}_3^-$ ) following exposure to sunlight (or other sources of ultraviolet light). Unraveling the reactions that follow photolysis of  $\text{NO}_3^-$  is critical in evaluating its role in the production of pollutant gases. Through the use of infrared (IR) spectroscopy, previous work has asserted that nitrate concentrations are split between two different molecular structures. Over time, the relative concentrations of the two structures shift due to influences within the immediate environment. We have examined the influence of hydroxyl radicals ( $\text{OH}\cdot$ ) upon nitrate using hydrogen peroxide as a radical source. Benzoic acid is used as a reporter by which we observe radical concentration. Thus, changes to the aqueous  $\text{NO}_3^-$  IR spectrum can be correlated to hydroxyl radical concentrations. Spectra were collected every five minutes for eight hours following a brief UV irradiation of the sample. The impact of temperature is assessed as well, both on the shift in peak intensities and on the kinetics of the reaction network. At this early stage of the project, we will present our preliminary data on aqueous nitrate at various temperatures, and the use of benzoic acid as a hydroxyl radical reporter. Through use of this array of variables, the role of hydroxyl radical in the production of  $\text{NO}_x$  and  $\text{O}_3$  will be clarified, so that models of the creation of these pollutants from natural resources can be refined and included into global climate change predictions.

## NOTES

[illegible]

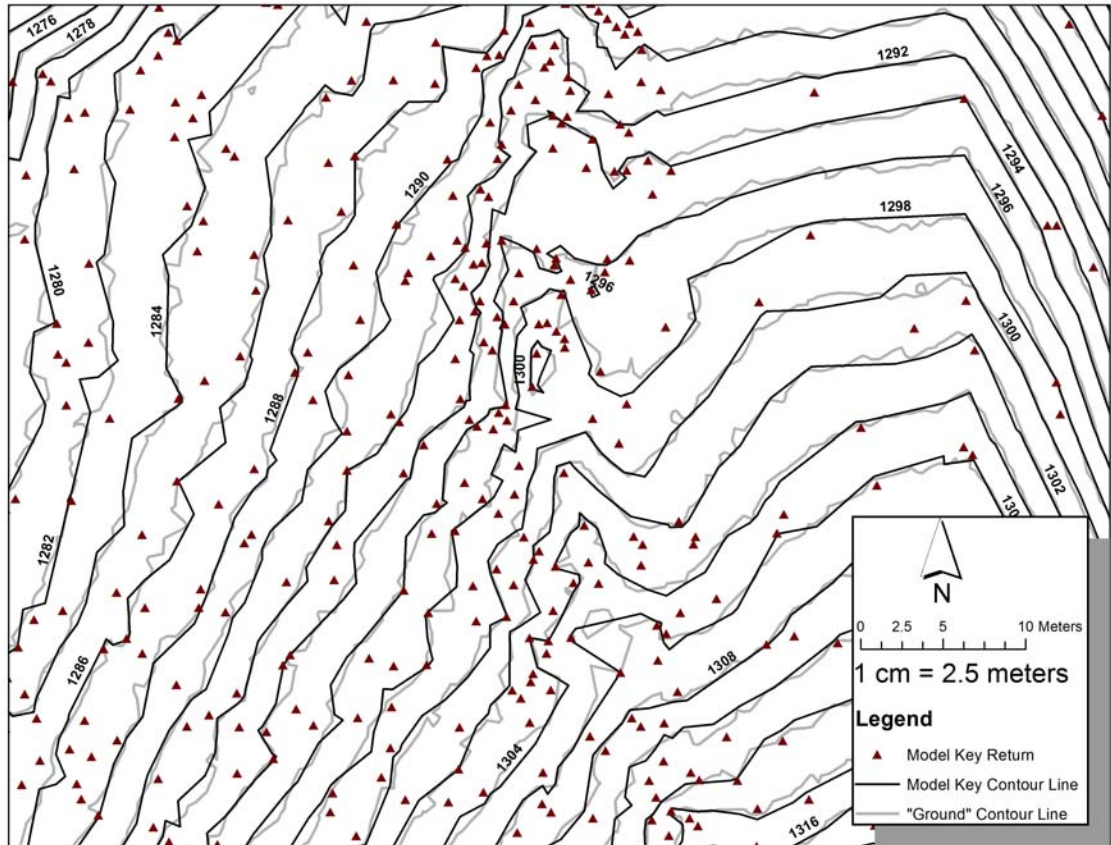
## DATA MINING THE DIGITAL TERRAIN: USING LiDAR “BARE EARTH” AND “MODEL KEY” RETURNS TO ASSESS WATERSHED TOPOGRAPHY

Demetrio P. Zourarakis  
Remote Sensing/GIS Analyst - Kentucky Division of Geographic Information  
Commonwealth Office of Technology  
100 Fair Oaks Ln.  
Frankfort, KY 40601  
502-564-6246  
demetrio.zourarakis@ky.gov

Accurate topographic data are critical for watershed modeling and management. High quality LiDAR derivative products, such as digital terrain models (DTM), digital surface models (DSM) and contour lines are becoming commonplace as a result of increasing data availability, together with a growing variety of software tools. LiDAR point clouds are routinely classified into “ground” (or “bare earth”) returns, and “model key” points – in essence a thinned-out subset of that class (ASPRS, 2012). The sensitivity of LiDAR measurements to very low, ground-level vegetation and micro relief creates the need to generate contour lines that are reflective of modeled – if not true, bare earth conditions. To that effect, contour lines are routinely derived from model key points to avoid the vagaries inherent in wholesale “ground” point elevations.

LiDAR survey data from the Kentucky portion of the Risk MAP Initiative were acquired in the Upper Cumberland River watershed (HUC 05130101), on April 2010 (FEMA 2010a). Survey points were collected at approximately 1.0 m ground sampling distance with no snow on the ground, rivers at or below normal levels, and under cloud-free conditions; points were assigned classes of: “ground” and “model key” in accordance with current classification schemas (FEMA, 2010b; USGS, 2010). A .las tile covering 2.323 square kilometers corresponding to the urban-forested land interface in the city of Corbin in Whitley County was used for this analysis (Kentucky Geography Network, 2012).

QCoherent™ LP360™ v.2011.1.54.0 and Esri® ArcGIS® Desktop v.10.0 SP3 were used to sample the LiDAR point cloud and to generate data sets and analytical derivatives. Elevation and slope ranged between 492.5 and 332.3 meters (mean= 369.8 meters; standard deviation= 28.1 m), and between 81.6 and 0 (mean=12.1 degrees; standard deviation= 10.0). Sets of contour lines were extracted from model key and “ground” digital elevation models (DEM-k and DEM-g, respectively). Geometric congruity between the two types of contour lines was sometimes appreciable, but more often than not discrepancies were substantial (*Figure 1*). Focal statistics derived from a normalized bare earth digital elevation model (DEM-n), created by subtracting DEM-g from the DEM-k are used to provide critical information on terrain rugosity and morphology, while at the same time to help explain some of the variation in LiDAR intensity values.



*Figure 1. LiDAR model key returns and contour lines comparison to “ground” contour lines. See text for explanation.*

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## THE WATERSHED ATLAS PROJECT

Brian D. Lee, Ph.D.  
&  
Corey L. Wilson  
Department of Landscape Architecture  
College of Agriculture  
University of Kentucky  
1100 Nicholasville Road  
S-305 Agriculture Science North  
Lexington, Kentucky 40546-0091  
(859) 257-7205  
blee@uky.edu

This interactive poster presentation demonstrates an approach that utilizes publically available geospatial data from the Kentucky Geography Network and other federal sources to visualize landscape indicators to describe watersheds. Initial grounding for this work can be found in Jones et al. (1997). By viewing the landscape from a watershed perspective, this atlas is intended to present an understanding of land use management decisions, as well as insight into how those decisions affects waterways and water. This project used the Hydrologic Unit Code (HUC)14 watersheds as the fundamental unit of analysis. Each of the 9,109 HUC14 subwatersheds spanning 13 river basins is described using over 100 indicators. All the indicators are in a format that allows visualization in tabular, graph, and map forms.

The atlas is divided into six sections by the following themes: Geographic Introduction, Geomorphic, Human, Vegetative, Riparian, and Specialty Indicators. An indicator glossary is included to provide source information and a description of each analysis. The geographic introduction section provides base information to introduce the basin and its subwatersheds and waterways in the context of notable landmarks. The second section provides a geomorphic watershed characterization that focuses on data attributes such as size, elevation, aspect, terrain, etc. Section three addresses the human modified aspects such as impervious cover, impervious cover change over time, and roadways in relationship to water resources, etc. Section four details the vegetative land cover of the watersheds with specific indicators focusing on percentage of agriculture and forest, as well as the relationship of agriculture on land slopes of three-percent and greater. In addition, this section characterizes changes in land cover type that occurred between 2001 and 2005 as well as 2001 and 2006. Section five focuses on stream and riparian area characteristics, and section six focuses on specialty indicators such as pollutant discharge elimination system points and regulated dams.

The primary benefit of characterizing the landscape from a watershed perspective is the ability to recognize the human influenced impacts using a flexible data approach

(Hawkins et al., 2000; Patil, 2002). This atlas can be used as a tool to identify landscape characteristics that are relevant to land management decisions particularly when water resources are concerned. For example, when watershed plans need to be made to reduce nutrient loading or identifying restoration potential (USEPA, 2005) these data can be used. A watershed-based approach for making decisions requires cities, counties, and states to recognize that though they may appear to be distinct entities, ecological features and processes connect them. This is an inherent argument for land decisions to be made with watershed characterizations in mind.

At this point in the process, there has been invested approximately two computer-processing years to develop this atlas. We expect another several calendar months of work to complete the planned indicators for the HUC14 scale subwatersheds. Once completed, these indicators will be derived for all the HUC12 scale subwatersheds to begin researching scale relationships.

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POTENTIAL FOR LEVELS OF ARSENIC AND CHROMIUM IN DRINKING  
WATER TO CONTRIBUTE TO THE HIGHER CANCER RATES FOR EASTERN  
KENTUCKY CITIZENS AS COMPARED TO THE REST OF THE STATE

Albert Westerman, PhD  
Phillip W. O'dell, P.G.  
Kentucky Division of Water  
200 Fair Oaks Lane  
Frankfort, KY 40601  
(502)-564-3410  
Albert.westerman@ky.gov  
Phillip.o'dell@ky.gov

Various sources have indicated that elevated amounts of heavy metals like arsenic (As) and chromium (Cr) in the drinking water and soil of Appalachia play a causative role in the region's high lung and colorectal cancer rates. In order to test the plausibility of the hypothesis that drinking water may be contributing to the recognized problem, the Division of Water (DOW) examined the levels of arsenic and chromium both in public and private water supplies statewide. We did not investigate levels of As and Cr in the soils.

We gathered monitoring data for treated drinking water from Kentucky's 519 Public Water Systems (PWS) ranging in size of as few as six (6) to as many as 730,611 customers. Monitoring data were also evaluated from commercial bottled water facilities. Assessed data included PWS monitoring from the past eleven years, January 2000 through September 2011. Drinking water data from 702 wells for arsenic and 498 for chromium were also evaluated and presented as part of the discussion. It should be noted that many of these samples were obtained from private drinking water wells sampled in response to a well owner's concern; therefore, the wells may bias the sampling towards problem areas.

In evaluating the PWS data, we pooled the information based on physiographic regions including the Eastern Coal Fields (27 counties), Western Coal Fields (10 counties), Bluegrass (44 counties), Mississippi Plateau (31 counties), and Jackson Purchase (8 counties). For purposes of evaluation of the groundwater data, additional regional groupings included the Ohio River Alluvium and an economic region referred to as the Golden Triangle, an area bounded by Louisville, Lexington and Northern Kentucky.

Arsenic and Chromium do not occur at levels of concern in any PWS across the state, including the commercial bottled water facilities. In fact, monitoring indicates that levels of As and Cr in public drinking water are consistently below possible health effects levels (i.e., below MCLs: total As is 0.010 mg/L and total Cr is 0.10 mg/L). Of the monitoring data collected over the last eleven years from the 519 PWS in Kentucky, **only one MCL violation was noted for any metal, including As and Cr (i.e., antimony in a December 2004 sampling at a PWS in Knox County).**

We examined the well data using the traditional EPA statistical averaging method and a second method known as the central tendency analysis (average, median). In the majority of the samples, metal concentrations were below the analytical detection limit and the two methods included that data in the analysis.

Total As and Cr levels were below concentrations of concern (MCLs) in groundwater in all regions of Kentucky including the Eastern and Western Coal Fields. Both statistical analysis methods resulted in similar low levels of As and Cr for each region.

Arsenic and chromium were not found at levels of concern in drinking water supplies in the Commonwealth of Kentucky, including water supplied by private drinking water wells and Public Water Systems. Speculation that the citizens living in the Eastern Kentucky Coal Field are uniquely exposed to heavy metals like arsenic and chromium in their drinking water supplies above those in other regions of the Commonwealth, does not appear to be a valid theory. In fact, statewide analytical sampling data from both public drinking water systems and drinking water wells indicates the levels of heavy metals are generally below that of health concern levels.

PATHOGEN TOTAL MAXIMUM DAILY LOAD  
FOR SOUTH ELKHORN CREEK WATERSHED

Lindell Ormsbee, Director; Ben Albritton, Scientist  
Kentucky Water Resources Research Institute  
228 MMRB University of Kentucky  
Lexington, KY 40506-0107  
Phone: 859-257-1299  
lormsbee@engr.uky.edu; benalbritton@yahoo.com

V. Chandramouli, Assistant Professor of Civil Engineering  
Department of Mechanical Engineering  
Purdue University Calumet  
Hammond, Indiana 46323  
cviswana@purduecal.edu

The study area is 170 square miles comprising the watersheds of the South Elkhorn Creek and its tributaries, Wolf Run, Town Branch, Steeles Run, and Lee Branch. Pathogens, as indicated by fecal coliform bacteria, impair the watershed for Primary Contact Recreation. The impairment was based on water samples taken during the primary contact recreation period of 2002. An HSPF computer model of the study area was developed to assess the current conditions and develop the TMDL. Sources of the impairment that were investigated and modeled included nonpoint sources such as agricultural and urban runoff, and point sources such as wastewater treatment plants and sanitary sewer overflows. After the model was calibrated for the hydrologic behavior of the watershed using rainfall and stream flow data, the model was calibrated to simulate the buildup and transport of fecal coliform bacteria. Literature provided initial estimates of fecal buildup from the various sources, but these estimates required further calibration to best fit the observed laboratory data. Using the calibrated model, pathogen load reductions were simulated until the model predicted in-stream concentrations of fecal coliform bacteria which satisfied the state water quality standards. The state water quality standards in terms of fecal coliform for the primary contact recreation season include a chronic criterion and an acute criterion. The chronic criterion states that fecal coliform cannot exceed 200 colonies per 100 ml measured as a geometric mean of at least five samples over a 30 day period, and the acute criterion states that no more than 20% of the individual samples can exceed 400 colonies per 100 ml. The simulated load (after reductions) resulting in the simultaneous satisfaction of both standards became the basis for the TMDL values. To achieve the TMDL, illegal point sources (straight pipes, failing septic systems, and sewer overflows or system leaks) needed to be eliminated. The percentage of load reductions required for nonpoint sources was most commonly 25%.

## NOTES

[illegible]

## NUTRIENT TMDL FOR TOWN BRANCH/WOLF RUN WATERSHED

Lindell Ormsbee, Director; Ben Albritton, Scientist  
Kentucky Water Resources Research Institute  
228 MMRB University of Kentucky  
Lexington, KY 40506-0107  
Phone: 859-257-1299  
lormsbee@engr.uky.edu; benalbritton@yahoo.com

V. Chandramouli, Assistant Professor of Civil Engineering  
Department of Mechanical Engineering  
Purdue University Calumet  
Hammond, Indiana 46323  
cviswana@purduecal.edu

The study area is 40 square miles comprising the watersheds of the Town Branch and Wolf Run creeks. Nutrients, as indicated by the limiting nutrient phosphorus, impair the watershed for Warm Water Aquatic Habitat. The impairment was based on water samples taken from March 2009 to March 2010. An HSPF computer model of the study area was developed to assess the current conditions and develop the TMDL. Sources of the impairment that were investigated and modeled were nonpoint sources such as agricultural and urban runoff, and point sources such as wastewater treatment plants and sanitary sewer overflows. After the model was calibrated for the hydrologic behavior of the watershed using rainfall and stream flow data, the model was calibrated to simulate the buildup and transport of phosphorus. Literature provided initial estimates of phosphorus buildup from the various sources, but these estimates required further calibration to best fit the observed laboratory data. Using the calibrated model, phosphorus load reductions were simulated until the model predicted in-stream concentrations of phosphorus which satisfied the state water quality targets. The state is in the process of developing nutrient standards, and at the time this study was conducted the state set a target for phosphorus of 0.3 mg/L measured as a geometric mean over a one year period. The simulated load (after reductions) resulting in the satisfaction of the target became the basis for the TMDL values. To achieve the TMDL, illegal point sources (straight pipes, failing septic systems, and sewer overflows or system leaks) needed to be eliminated. The model indicated that conditions measured by the target process did not require reductions for nonpoint sources, but did necessitate a substantial reduction in the phosphorus concentration of the wastewater treatment plant discharging within the watershed.

## NOTES

[illegible]

ANALYZING MONTHLY TRENDS OF RAINFALL AND TEMPERATURE IN  
NORTHWEST INDIANA  
TO EXAMINE CLIMATE CHANGE

Ryan Ordonez Haggard, V. Chandramouli, Sivakumar Buddharaju  
Civil Engineering Student, Assistant Professor of Civil Engineering  
Department of Mechanical Engineering  
Graduate Student, Department of Electrical Engineering  
Purdue University Calumet, Hammond, Indiana 46323  
cviswana@purduecal.edu

Long term monthly trends of rainfall and monthly mean temperatures were examined using the Seasonal Mann Kendall testing procedure in this study. The main objective of this work is to study the changes in low flow regime in northwest Indiana and understand the influence of rainfall, temperature and landuse pattern changes. Three rainfall stations with daily rainfall observations of 50 years or more were considered for this purpose (Table 1).

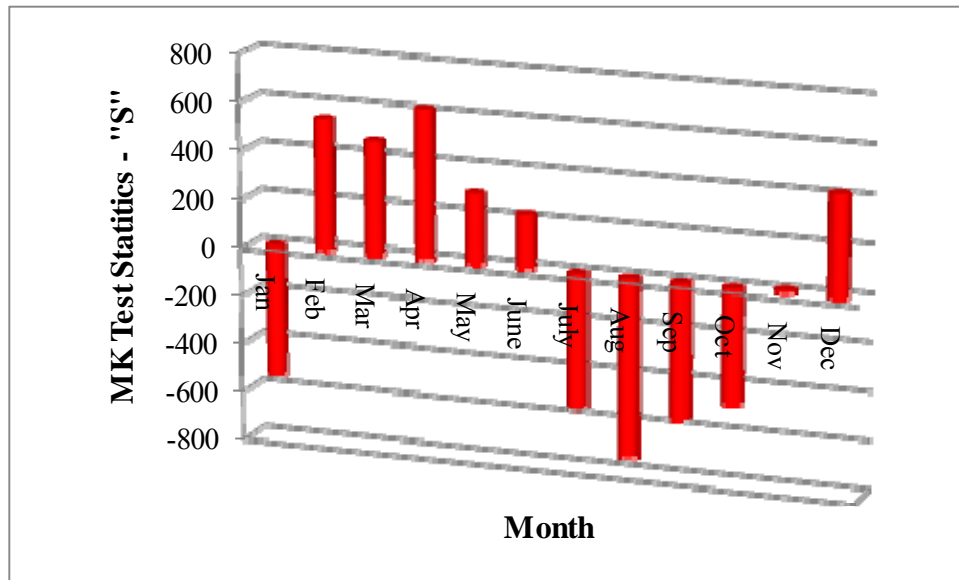
**Table 1. Monthly Rainfall and Mean Monthly Temperature observations (Data Source NOAA)**

<b>Station Name</b>	<b>Data Available from</b>
La Porte	Apr 1897
Valparaiso	Jan 1900
Lowell	Aug 1963

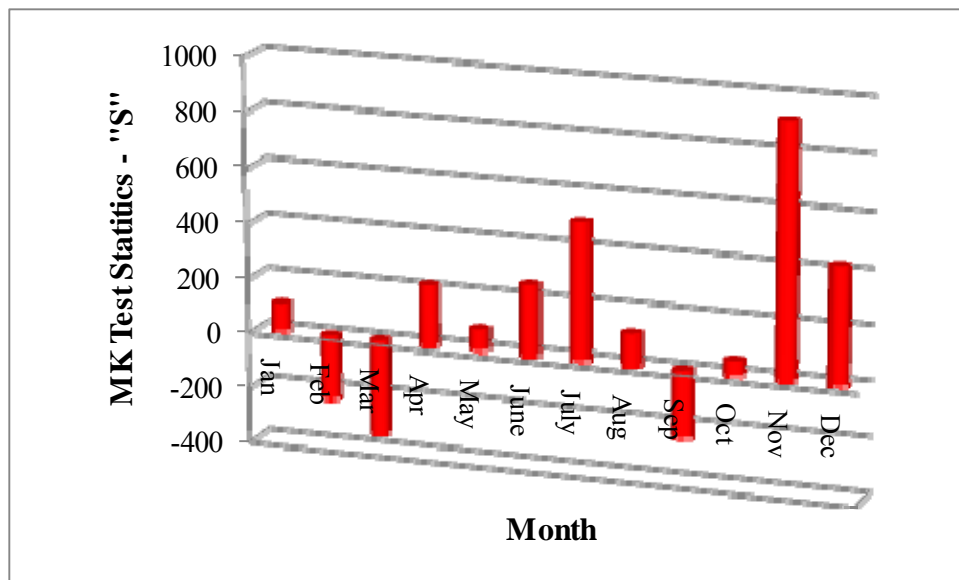
A non parametric testing procedure called the Mann-Kendall (MK) test was used for analyzing trends in the single station data series. The MK test is popularly used to identify trends in climatological time series (Zhang et al 2001). Chronological series are used in this method. When a time series with seasonal fluctuations is analyzed, a slight change was proposed by Hirsch and Slack (1984). In this seasonal MK test,  $S_i$  is calculated using for each season considered (Helsel and Hirsch, 2002). When  $S$  is positive, it indicates an upward trend and negative value indicates a downward trend.

When the test was conducted on monthly mean temperatures and monthly rainfall, the results were not showing trends at 95% confidence level. However, the variations of “S” were captured and presented in Figure 1 and 2 for Valparaiso Station. February to June showed an increasing mean monthly temperature and July to October showed a decreasing trend. November showed an increasing rainfall trend at 95% confidence limit.

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**Figure 1. Monthly Temperature Variations – Valparaíso MK-Test Statistics**



**Figure 2. Monthly Rainfall Variations – Valparaíso MK-Test Statistics**

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## EXAMINING CLIMATE CHANGE INDICES OF INDIANA

Ramesh<sup>1</sup>, S.V.T, V.Chandramouli<sup>2</sup>, Ravi Chittamuru<sup>3</sup>

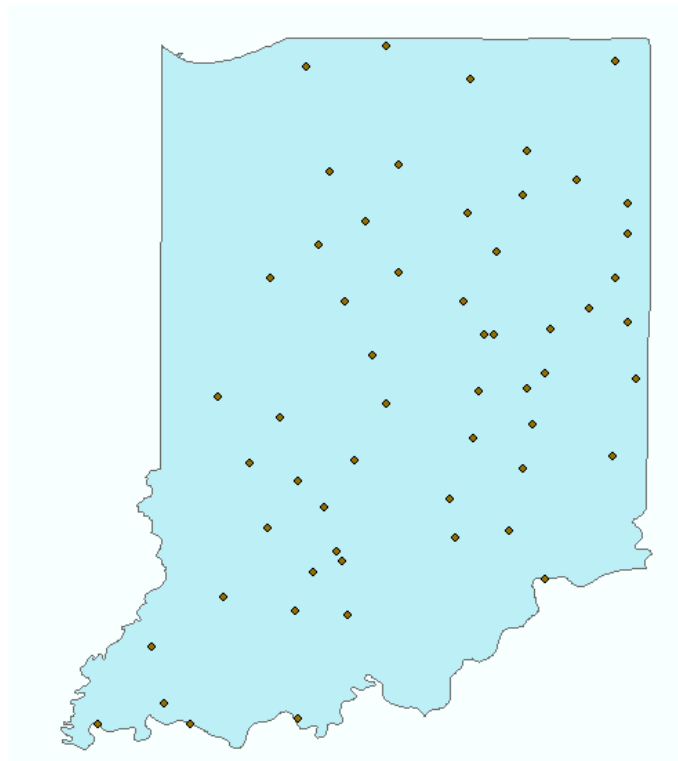
<sup>1</sup>Assistant Professor, Civil Engineering Department  
Florida Atlantic University, Boca Raton, Florida, 334 31

<sup>2</sup>Assistant Professor of Civil Engineering, Mechanical Engineering Department  
Purdue University Calumet, Hammond, Indiana, 46323  
cviswana@purduecal.edu

<sup>3</sup>Graduate Student, ECE Department  
Purdue University Calumet, Hammond, Indiana, 46323

### Introduction

This research examines climate change indices to understand the changes in Indiana rainfall patterns during the last 30 years. For this purpose, daily rainfall data from 1950 to 2010 were used. In total, 57 rain gage stations located in Indiana were considered for this analysis.



**Figure 1. Rain gage stations considered in this analysis**

## Analysis

Climate indices namely maximum one day precipitation (RX1day), maximum five day precipitation (RX5day), simple daily index, count of precipitation days with observed daily rainfall greater than 10 mm (R10mm), count of precipitation days with observed daily rainfall greater than 20 mm, consecutive dry days (CDD), and consecutive wet days (CWD) were calculated using the rainfall data. Daily series were split into two groups (1950 to 1980 and 1981 to 2010). Climate indices were calculated for the two time periods for all the regions and the indices were documented (Table 1). Climate indices in group 1 and group 2 were compared to check variation. Further, calculated indices were compared by dividing Indiana into four sub regions (northeast, northwest, southeast and southwest). The numbers of rain gage stations considered in each region are also given in Table 1. After finding the indices for individual stations, they were averaged for each sub region.

**Table 1. Regional climate change indices RX1day, RX5day and CDD**

Sub regions	Number of Stations	RX1day		RX5day		CDD	
		1950-1980	1981-2010	1950-1980	1981-2010	1950-1980	1981-2010
North East	16	4.64	4.94	7.28	7.83	6429	6271
North West	10	5.67	5.96	7.65	9.91	6563	6079
South East	12	4.58	4.77	7.08	7.29	6519	6318
South West	19	5.85	5.83	8.67	9.22	6647	6539

In the recent 30 years, more wet days were observed. RX1day indicates that in three subregions (northeast, northwest and southeast), there was an increase in the maximum one day precipitation. It remained the same in the southwest sub region of Indiana. On the other hand, 5 day maximum rainfall fall increased in all of the regions. Consecutive dry days decreased in all the regions. Northwest had a large decrease indicating increased precipitation activity.

**Acknowledgement:** Dr. Viswanathan acknowledges the support provided by DNR, IDEM, Indiana small grant.

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